Introductory Astronomy **NAME:**

Homework 10: Solar System Formation: Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems ($\sim$ 50–70 %) will turn up on tests.

Answer Table

Name:

	a	b	c	d	e		a	b	c	d	e
1.	O	O	O	O	O	37.	O	O	O	O	O
2.	O	O	O	O	O	38.	O	O	O	O	O
3.	O	O	O	O	O	39.	O	O	O	O	O
4.	O	O	O	O	O	40.	O	O	O	O	O
5.	O	O	O	O	O	41.	O	O	O	O	O
6.	O	O	O	O	O	42.	O	O	O	O	O
7.	O	O	O	O	O	43.	O	O	O	O	O
8.	O	O	O	O	O	44.	O	O	O	O	O
9.	O	O	O	O	O	45.	O	O	O	O	O
10.	O	O	O	O	O	46.	O	O	O	O	O
11.	O	O	O	O	O	47.	O	O	O	O	O
12.	O	O	O	O	O	48.	O	O	O	O	O
13.	O	O	O	O	O	49.	O	O	O	O	O
14.	O	O	O	O	O	50.	O	O	O	O	O
15.	O	O	O	O	O	51.	O	O	O	O	O
16.	O	O	O	O	O	52.	O	O	O	O	O
17.	O	O	O	O	O	53.	O	O	O	O	O
18.	O	O	O	O	O	54.	O	O	O	O	O
19.	O	O	O	O	O	55.	O	O	O	O	O
20.	O	O	O	O	O	56.	O	O	O	O	O
21.	O	O	O	O	O	57.	O	O	O	O	O
22.	O	O	O	O	O	58.	O	O	O	O	O
23.	O	O	O	O	O	59.	O	O	O	O	O
24.	O	O	O	O	O	60.	O	O	O	O	O
25.	O	O	O	O	O	61.	O	O	O	O	O
26.	O	O	O	O	O	62.	O	O	O	O	O
27.	O	O	O	O	O	63.	O	O	O	O	O
28.	O	O	O	O	O	64.	O	O	O	O	O
29.	O	O	O	O	O	65.	O	O	O	O	O
30.	O	O	O	O	O	66.	O	O	O	O	O
31.	O	O	O	O	O	67.	O	O	O	O	O
32.	O	O	O	O	O	68.	O	O	O	O	O
33.	O	O	O	O	O	69.	O	O	O	O	O
34.	O	O	O	O	O	70.	O	O	O	O	O
35.	O	O	O	O	O	71.	O	O	O	O	O
36.	O	O	O	O	O	72.	O	O	O	O	O

1. Did you complete reading-homework-self-testing for the Introductory Astronomy Lecture (IAL) by the weekly due date?

   a) YYYessss! b) Jawohl! c) Da! d) Sí, sí. e) OMG no!

2. We will probably never be able to understand how our Solar System formed in exact detail, but can understand in more general terms how it formed by relying on various kinds of evidence: e.g.,

   a) star formation regions that we observe, extrasolar planetary systems (of which **399** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **DINOSAUR FOSSILS**.
   b) star formation regions that we observe, extrasolar planetary systems (of which **3992** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **BIOLOGY**.
   c) star formation regions that we observe, extrasolar planetary systems (of which **3992** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **MODELING**.
   d) star formation regions that we observe, extrasolar planetary systems (of which **3** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **MODELING**.
   e) star formation regions that we observe, extrasolar planetary systems (of which **399** are known as of 2023jun23), relics of the formation process (e.g., leftover planetesimals or fragments thereof including primitive meteorites), and **WISHFUL THINKING**.

3. "Let's play *Jeopardy*! For $100, the answer is: This principle (i.e., which is really a guiding hypothesis) explains coincidences in physics and in the universe that are favorable to life by stating that without these coincidences we would not be here to observe the universe. The opposite point of view is that such coincidences were dictated by the strict physical necessity of some underlying theory of everything. Of course, if the second view is correct, one wonders why the theory of everything in itself happens to be compatible with life (i.e., be biophilic)."

   What is the ____________ Principle, Alex?

   a) Anthropic b) Copernican c) Cosmological d) Biophilic e) Peter

4. "Let's play *Jeopardy*! For $100, the answer is: He/She was the first proposer of the nebular hypothesis for the origin of the Solar System in the context of Newtonian physics."

   Who is ____________, Alex?

   a) composer Johann Sebastian Bach (1685–1750) b) adventurer and writer Giovanni Jacopo Casanova (1725–1798) c) astronomer Caroline Herschel (1750–1848) d) English general and statesman John Churchill, Duke of Marlborough (1650–1722) e) philosopher Immanuel Kant (1724–1804)

5. Radioactive dating:

   a) uses radioactive decay to determine age.
   b) uses radioactive decay to determine mass.
   c) is useless in practice.
   d) uses radioactive decay to determine the half-life of a radioactive isotope.
   e) sounds more exciting than it is.

6. Radioactive dating of a rock gives the:

   a) age of the radioactive isotopes in the rock.
   b) time since the rock was last exposed to sunlight.
   c) time since the rock was formed provided the pre-formation daughter element abundance **CAN** be distinguished from the post-formation daughter element abundance.
   d) time since the rock was formed even when the pre-formation daughter element abundance **CANNOT** be distinguished from the post-formation daughter element abundance.
   e) time since the rock was last exposed to radioactivity.

7. Say you have a radioactive nucleus with half-life $t_{1/2}$. You've observed it for n half-lives. What is the probability that it will decay in the next half-life? **HINT:** Think about tossing coins.

a) 1. b) 0. c) $1 - 1/2^{n+1}$. d) 1/2. e) $1 - 1/2^n$.

8. You have a sample of rock in which the ratio of ^{40}K (radioactive potassium) to ^{40}Ca (stable calcium) is 1 to 1. The half-life of ^{40}K is about 1.3 billion years. Assuming the rock was calcium-free at formation, what is the approximate time since the rock was formed?

   a) 1.3 billion years. b) 2.6 billion years. c) Only a few years at most.
   d) 13 billion years. e) 4.6 billion years.

9. A sample is initially pure radioactive $^{238}_{92}$U (isotope uranium-238). After four half-lives how much $^{238}_{92}$U is left?

   a) 1/16. b) 1/2. c) 1/4. d) 1/10. e) None.

10. In dense environments, decay energy from radioactive decay is usually converted into:

    a) macroscopic kinetic energy. b) heat energy. c) macroscopic gravitational potential energy. d) macroscopic magnetic field energy. e) reindeer energy.

11. The planets probably formed out of:

    a) a disk of gas and dust that surrounded the early Sun or proto-Sun.
    b) material pulled out of the Sun by a star that passed closely in the remote past.
    c) pure hydrogen gas.
    d) pure helium gas.
    e) carbon dioxide gas.

12. The planets orbit approximately in a single plane probably because:

    a) the early solar nebular magnetic field forced them to form in a plane.
    b) pure luck.
    c) pure bad luck.
    d) they formed out of the protoplanetary disk of material that formed about the proto-Sun.
    e) a passing star pulled them into a plane long after formation.

13. Volatiles could not condense much in the inner Solar System, and thus did not get incorporated in massive amounts into the inner planets. But the Sun is mainly hydrogen and helium which are certainly volatiles. Why in the Sun and not in the inner planets?

    a) Because of the Sun's magnetic field.
    b) The proto-Sun grew massive enough to hold its volatiles by **GRAVITATION** despite the high temperature it reached.
    c) The proto-Sun grew massive enough to hold its volatiles by the **PRESSURE FORCE** despite the high temperature it reached.
    d) The hydrogen and helium that went into the Sun was sticky.
    e) The difference has no plausible explanation.

14. The solar wind probably flushed much of the primordial gas and dust out of the Solar System during its formation. Say that the solar wind has a speed of 400 km/s. Pluto is about 40 astronomical units from the Sun and the astronomical unit is about 1.5×10^{13} cm. How long does it take the wind to travel from the Sun to Pluto? About:

    a) 1.5×10^7 s or half a year. b) 1.5×10^7 s or 10 years. c) 1.5×10^{13} s. d) 1×10^5 s or a day. e) 1×10^5 s or 10 day.

15. Planetesimals are:

    a) objects of kilometer size or greater that are always lost from the Solar System during planet formation.
    b) objects of kilometer size or greater that can mutually accrete (largely because of gravitational attraction) to form protoplanets.
    c) centimeter size grains that mutually accrete (largely because of gravitational attraction) to form protoplanets.
    d) very tiny planets.
    e) always made of ices.

16. The planetary formation sequence as currently understood is:

a) streaming instability (plus collective-self-gravitation accretion) changing gas to grains, condensation of grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
b) streaming instability (plus collective-self-gravitation accretion) changing gas to planetesimals, further streaming instability (plus collective-self-gravitation accretion) changing planetesimals to protoplanets.
c) condensation of gas to grains, streaming instability (plus collective-self-gravitation accretion) changing grains to planetesimals, further streaming (plus instability/collective-self-gravitation accretion) changing planetesimals to protoplanets.
d) condensation of gas to grains, streaming instability (collective-self-gravitation accretion) changing grains to planetesimals, gravitational accretion of planetesimals to protoplanets.
e) gravitational coalescence of gas to grains, streaming instability (collective-self-gravitation) changing grains to planetesimals, gravitational accretion of planetesimals to protoplanets.

17. Two planetesimals are most likely to totally bind together if:

a) they are moving toward each other at high relative speed for a head-on collision.
b) they are moving directly away from each other.
c) they are at very different distances from the star or protostar.
d) they are invisible.
e) they approach each other with low relative velocity.

18. Two planetesimals are most likely to fragment and **NOT** to bind together if:

a) they are moving toward each other at high relative speed for a head-on collision.
b) they are moving directly away from each other.
c) they are at very different distances from the star or protostar.
d) they are invisible.
e) they approach each other with low relative velocity.

19. What is the origin of the helium in the Sun's atmosphere, in the Sun's core, and in Jupiter?

a) The helium in the Sun's atmosphere and Jupiter is **PRIMORDIAL**: i.e., it was the helium present when the Solar System formed: most of this primordial helium formed in the Big Bang (or so the theory goes) and some in earlier generations of stars. The helium in Sun's core is partially primordial and partially from the **NUCLEAR BURNING** of the hydrogen that goes on in the Sun's core.
b) All this helium is **PRIMORDIAL**: i.e., it was the helium present when the Solar System formed: most of this primordial helium formed in the Big Bang (or so the theory goes) and some in earlier generations of stars.
c) All the helium in the Solar System was formed in the **SUN'S CORE** by the nuclear burning of helium. Convection transported this helium to the surface of the Sun and the solar wind transported some of it into the outer solar system where of it got accreted onto the proto-Jupiter.
d) All the helium in the Solar System was formed by nuclear burning of hydrogen that occurred **WHERE THE HELIUM IS NOW FOUND**. Thus, there was nuclear burning on the surface of the Sun and and in Jupiter in the early days of the Solar System. Of course, nowadays the nuclear burning of hydrogen occurs only in the Sun's core.
e) The chemical breakup of **PRIMORDIAL WATER** (i.e., water that existed before the Solar System formed) left the helium in all of these sites.

20. In Solar System planetary formation:

a) the ices condensed mostly near the Sun; the rocky and metallic material in the outer Solar System.
b) the ices condensed everywhere; the rocky and metallic material in the inner Solar System only.
c) the ices condensed mainly in the outer Solar System. The rocky and metallic material condensed everywhere roughly speaking.
d) the ices condensed only near what became Jupiter. The rocky and metallic material condensed only in the neighborhood of what became the Earth.
e) the ices condensed only near what became Saturn. The rocky and metallic material condensed only in the neighborhood of what became the Earth.

21. "Let's play *Jeopardy*! For \$100, the answer is: These Solar System bodies are thought to form according to one of two possible theories. Theory 1: they start as rocky/icy protoplanets that are massive enough to gravitationally attract and hold abundant hydrogen and helium gas. Theory 2: they start

as gravitationally collapsed dense cores of hydrogen and helium just as stars do and grow by further gravitational accretion of abundant hydrogen and helium."

What are ____________, Alex?

a) gas giant planets b) rocky or terrestrial planets c) minor planets or an asteroids d) Kuiper Belt objects or a trans-Neptunian objects e) mirror matter planets

22. Asteroids are:
    a) very probably leftover **ICY** planetesimals (or planetesimal fragments) from the formation of the Solar System. Some have undergone internal-heat geological evolution.
    b) very probably leftover **GASEOUS** planetesimals (or planetesimal fragments) from the formation of the Solar System.
    c) very probably leftover **ROCKY** planetesimals (or planetesimal fragments) from the formation of the Solar System. Some have undergone internal-heat geological evolution. They may have some ice too.
    d) **ICY** planetesimals that formed **OUTSIDE** of the Solar System. Some have undergone internal-heat geological evolution.
    e) **ROCKY** planetesimals that formed **OUTSIDE** of the Solar System. Some have undergone internal-heat geological evolution.

23. Comets are:
    a) very probably leftover **ICY/CARBONACEOUS** planetesimals (or planetesimal fragments) from the formation of the Solar System.
    b) very probably leftover **ROCKY** planetesimals (or planetesimal fragments) from the formation of the Solar System.
    c) very probably leftover **GASEOUS** planetesimals (or planetesimal fragments) from the formation of the Solar System.
    d) **ICY/CARBONACEOUS** planetesimals that formed outside of the Solar System.
    e) **ROCKY** planetesimals that formed outside of the Solar System.

24. Both gravitational collapse and collisions tend to cause:
    a) cooling. The heat from the bodies gets transformed into bulk kinetic energy and gravitational potential energy.
    b) plate tectonics.
    c) heating. The gravitational potential energy and bulk kinetic energy of the bodies gets randomized into microscopic kinetic energy.
    d) plate tectonics. The gravitational potential energy and bulk kinetic energy of the bodies sets up convective flows which brings magma to the surface of the protostars. The magma pushes about the crustal plates.
    e) magnetic fields which then cause the bodies to explode apart.

25. In one kind of analysis, the evolution of rocky/icy bodies in the solar system has been divided in to four stages. Not all rocky/icy bodies will go through all stages. These stages in probable time order are:
    a) nuclear differentiation, heavy bombardment, flooding by liquid nitrogen and/or liquid helium, and plate tectonics.
    b) nuclear differentiation, light bombardment, flooding by liquid nitrogen and/or water, and plate tectonics.
    c) nuclear differentiation, light bombardment, flooding by lava and/or water, and plate tectonics.
    d) chemical differentiation, light bombardment, flooding by lava and/or water, and plate tectonics.
    e) chemical differentiation, heavy bombardment, flooding by lava and/or water, and continuing geologic evolution.

26. In planet formation, the chemical differentiation stage is the stage:
    a) of heavy cratering.
    b) of heavy cratering and lava flows.
    c) where the molten materials of the early planets separated under the action of **GRAVITY**. The **DENSER** materials sank to the deeper regions; the **LESS DENSE** materials rose to the upper regions.

d) where the molten materials of the early planets separated under the action of **MAGNETIC FIELDS**. The **DENSER** material sank to the deeper regions; the **LESS DENSE** materials rose to the upper regions.
e) where the molten materials of the early planets separated under the action of the **SOLAR WIND**. The **LESS DENSE** material sank to the deeper regions; the **DENSER** materials rose to the upper regions.

27. Mainly by studying the variations in lunar crater density per unit area and the variations in ages of rocks from the lunar highlands and maria, Solar System astrophysicists have concluded that there was a period of heavy bombardment by various Solar System bodies. This heavy bombardment:

    a) was about 65 million years ago. b) was about 100 to 65 million years ago. c) covered about the first billion years of the Solar System after formation. d) was about 15 to 10 billion years ago. e) was coincident with the last ice age.

28. Why is almost every Solar System body with a **SOLID** surface scarred by craters?

    a) In the **10 BILLION YEARS** since the Solar System formed there has been a continuous increasing bombardment on solar system bodies by other Solar System bodies that was heaviest at early times in the heavy bombardment phase of the Solar System. Those bodies without solid surfaces can show impact effects only briefly. Those bodies with ongoing active geological activity (based on internal heat/erosion) erase traces of all but the most recent craters. But most solid-surface bodies do not have much active internal-heat/erosion-based geology. On these bodies cratering is principally erased only by newer cratering which does not of course erase the scarring.
    b) In the **4.6 BILLION YEARS** since the Solar System formed there has been a continuous bombardment on solar system bodies by other Solar System bodies that was heaviest at early times in the heavy bombardment phase of the Solar System. Those bodies without solid surfaces can show impact effects only briefly. Those bodies with ongoing active geological activity (based on internal heat/erosion) erase traces of all but the most recent craters. But most solid-surface bodies do not have much active internal-heat/erosion-based geology. On these bodies cratering is principally erased only by newer cratering which does not of course erase the scarring.
    c) The heaviest bombardment of Solar System bodies by other Solar System bodies has occurred in the last **100 MILLION YEARS**. This bombardment has cratered almost all the solid surfaces. It has also probably been responsible for the dinosaur extinction circa 65 million years ago. The likely deep impact of kilometer-scale asteroid 1997 XF_{11} on Earth in 2028 is just part of this bombardment phase.
    d) Most solid bodies in the Solar System have suffered heavy continuous volcanism: the asteroids most of all. The craters are mostly volcanic, not impact, in origin.
    e) The Earth isn't scarred by craters.

29. The rocky bodies in the Solar System from the largest asteroids upward in mass probably all experienced to some degree geological activity caused by:

    a) internal heat from formation (i.e., primordial heat) and past and in some cases current radiogenic heating.
    b) liquid water erosion.
    c) hydrogen enbrittlement.
    d) internal heat from the red giant phase of the Sun.
    e) ice ages.