Introductory Astronomy **NAME:**

Homework 21: Star 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 the intro astro web lecture before the **SECOND DAY** on which the lecture was lectured on in class?

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

2. The life history of our own star, the Sun, is known to us by:

   a) direct observations of all of its stages.
   b) direct observations of most of its stages plus observations of other stars in all their stages and modeling.
   c) direct observations of its current stage plus observations of other stars in all their stages and modeling.
   d) modeling alone.
   e) sheer guesswork.

3. The interstellar medium (ISM) consists of:

   a) planets. b) molecular clouds only. c) stars. d) dust only. e) gas and dust.

4. In modern astronomy, a nebula (plural nebulae) is a:

   a) cloud of a gas in space. b) large main sequence star. c) small main sequence star. d) bright star. e) young star.

5. The dense, cold component of the interstellar medium from which stars are believed to form is made of:

   a) H II (ionized hydrogen) regions. b) white dwarfs. c) protostars. d) Lyman-Alpha forests. e) molecular clouds.

6. The composition of molecular clouds in the interstellar medium is dominated by:

   a) carbon dioxide. b) molecular oxygen only. c) helium gas only. d) amino acids. e) molecular hydrogen gas and helium gas.

7. Molecular clouds are probably about 1 per cent dust by mass.

   a) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
   b) The dust is **VERY IMPORTANT** to these clouds. It is **COMPLETELY TRANSPARENT** to visible and ultraviolet light, and allows plenty of hard electromagnetic radiation into the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Dust tends to promote molecule formation and molecules tend to need dust. Thus, whenever you have a lot of dust, you often have molecules and vice versa.
   c) The dust is **COMPLETELY UNIMPORTANT** to these clouds. True, the dust is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.
   d) The dust is **VERY IMPORTANT** to these clouds. It is **HIGHLY OPAQUE** to visible and ultraviolet light, and so keeps most hard electromagnetic radiation out of the inner regions of the clouds. This prevents the destruction of molecules by hard radiation. Moreover, it is probable that many molecules form on dust grains: free atoms stick onto the grains, meet there, bond, and then escape in molecular form: i.e., the grains act as catalysts. Nevertheless, there are plenty of molecular clouds that are **COMPLETELY DUST-FREE**. In such clouds, the whole process of star formation is laid bare to visible light observers.

e) The presence of this dust is just coincidental. It just happens that where there is dust there are molecular clouds, and where there is no dust there arn't. Things could be entirely otherwise; they just arn't.

8. Interstellar dust probably varies widely in composition, size scale, and structure. But there some ideas about typical dust that are generally accepted.

   a) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\mathrm{m} = 10^{-6}\,\mathrm{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\mathrm{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **VOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **NONVOLATILES** condense out on the cores.
   b) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\mathrm{m} = 10^{-6}\,\mathrm{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\mathrm{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.
   c) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\mathrm{m} = 10^{-6}\,\mathrm{m}$ in size, but it won't be perfectly spherical. There may be a core of **NONVOLATILE** material of order $0.05\,\mu\mathrm{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **VOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms in **STELLAR WINDS AND SUPERNOVA EJECTA**. There relatively dense **NONVOLATILES** condense out forming the cores as the ejected gas cools. As the gas cools more, **VOLATILES** condense out on the cores.
   d) Although size scale probably varies widely, a typical dust grain may be of order $1\,\mu\mathrm{m} = 10^{-6}\,\mathrm{m}$ in size, but it won't be perfectly spherical. There may be a core of **VOLATILE** material of order $0.05\,\mu\mathrm{m}$ consisting of silicates (silicon and oxygen compounds that make up most terrestrial rock), iron, or graphite. The **GRAIN MANTLE** may be mostly **NONVOLATILE ICES**: e.g., H_2O (water ice), CO_2 (carbon dioxide ice or dry ice), CH_4, and NH_3. The grain surface may have complex molecules forming tarry substances. Dust probably forms inside the event horizons of **BLACK HOLES**. There relatively dense **NONVOLATILES** condense out forming the cores as the infalling gas cools. As the gas cools more, **VOLATILES** condense out on the cores. The dust then escapes scot-free from the black hole.
   e) The dust is found under sofas and on other untouched surfaces. It gets there by settling out the air. One often sees dust in air the reflecting bright sunlight.

9. "Let's play *Jeopardy*! For $100, the answer is: It happens whenever a star changes its luminosity and/or its surface temperature."

   What is ____________, Alex?

   a) explodes b) collapses c) turns green d) becomes a white dwarf e) movement on the Hertzsprung-Russell (HR) diagram

10. Star formation in a dusty molecular cloud probably requires some triggering event to initiate the collapse to dense cores that will become stars. Two possible trigger mechanisms are:

    a) **SUPERNOVAE** which compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
    b) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **CLOUD-CLOUD COLLISIONS** which also compress the colliding molecular clouds.
    c) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **PROTOSTAR-PROTOSTAR COLLISIONS** which also compress the molecular clouds.

d) **WHITE DWARFS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.
e) **WHITE HOBBITS** which ram into and thereby compress molecular clouds and **BLACK HOLE FORMATION** which also compresses the molecular clouds.

11. In a **FREE-FALL** contraction of part of molecular cloud:

a) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces slow the fall from the beginning.
b) the part starts fall to toward a high density point because of gravitational attraction. Pressure forces are negligible in slowing the fall because it is a free-fall contraction.
c) the entire molecular cloud collapses to form a black hole.
d) the part collapses to form a black hole.
e) planetesimals collide and break apart.

12. The collapsing dense regions that develop into stars and initially have temperatures of order 10 K are called:

a) dense cores. b) dilute cores. c) main sequence stars. d) white dwarfs. e) rotten cores.

13. A protostar is sometimes conveniently defined to be a:

a) star that can no longer burn hydrogen to produce heat energy.
b) white dwarf.
c) dense core of gas contracting to become a star that is hot enough to radiate in the infrared, but not yet sufficiently hot for nuclear burning.
d) molecular cloud that will become a star.
e) giant molecular cloud that will become a star.

14. The contraction of a protostar is halted eventually by:

a) the thermal energy generated by the contraction which **DECREASES** the gas pressure inside the protostar.
b) the thermal energy generated by the contraction which **INCREASES** the gas pressure inside the protostar.
c) the action of magnetic fields.
d) the action of the dynamo effect.
e) the heat generated by the turning on of nuclear burning which **INCREASES** the gas pressure inside the protostar.

15. Star formation in giant molecular clouds often results in the formation of OB associations: collections of hot, bright OB stars that ionize the surrounding molecular cloud and evaporate dust because of their strong ultraviolet emission. The gas region ionized by an OB associations is called a/an:

a) H II region. b) small molecular cloud. c) a black hole. d) a dark cloud. e) He region.

16. "Let's play *Jeopardy*! For $100, the answer is: They are relatively thin, round objects consisting of gas and/or dust and/or particles: the material goes around some large astro-body in nearly circular orbits of varying radii in the same direction."

What are ____________, Alex?

a) CDs b) planets c) disks d) satellites e) projectiles

17. Disk formation is:

a) a unique event that happened only in the case of the formation of the Sun.
b) a common event in star formation as far as astronomers can tell.
c) a process in nuclear burning.
d) never observed in star formation.
e) responsible for the heating up of the protostar.

18. Disk formation is believed to happen fairly generally:

a) in star formation, in the formation of accretion disks about putative black holes, and in the **formation of spiral galaxies**. In the case of black holes, matter is **sprayed out** of the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk.

b) in star formation, in the formation of accretion disks about black holes, and in the **formation of spiral galaxies**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **gravitational captured** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **cools down**.

c) in star formation, in the formation of accretion disks about black holes, and in the **formation of spiral galaxies**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **gravitational captured** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **heats up** due to infall kinetic energy being transformed into heat. Consequently, the infalling material radiates electromagnetic radiation. The object Sgr A^* near or at the dynamical center of the Milky Way, thought to be a black hole of mass of order $3 \times 10^6\,M_\odot$, is a strong radio source.

d) in star formation, in the formation of accretion disks about black holes, and in the **formation of impact craters**. In the case of supermassive black holes at the centers of galaxies, it is thought that matter, at least originally, is somehow **gravitational captured** by the black hole in random orbits and in a collisional-relaxation-dissipation process, similar to what happens in star formation, relaxes into a disk. This matter gradually loses rotational energy through viscous forces in the disk and spirals into the black hole. While spiraling into the black hole the matter **cools down**.

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