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 (∼ 50–70 %) will turn up on tests.

Answer Table

	a	b	c	d	e
1.	O	O	O	O	O
2.	O	O	O	O	O
3.	O	O	O	O	O
4.	O	O	O	O	O
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25.	O	O	O	O	O
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27.	O	O	O	O	O
28.	O	O	O	O	O
29.	O	O	O	O	O
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35.	O	O	O	O	O
36.	O	O	O	O	O

Name:

	a	b	c	d	e
37.	O	O	O	O	O
38.	O	O	O	O	O
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46.	O	O	O	O	O
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70.	O	O	O	O	O
71.	O	O	O	O	O
72.	O	O	O	O	O

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001 qmult 00007 1 4 1 easy deducto-memory: reading done 2

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!

   SUGGESTED ANSWER: (a),(b),(c),(d)

   Wrong answers:
   e) As Lurch would say AAAARGH.

   Redaction: Jeffery, 2008jan01

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040 qmult 00100 1 4 3 easy deducto-memory: life history of Sun
Extra keywords: Sunlife

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.

   SUGGESTED ANSWER: (c)

   We only directly observe the Sun in its current stage: i.e., the middle main sequence stage. The Sun has been there all of human history and will be there all of foreseeable human history.

   Wrong answers:
   e) "Sheer" and "guesswork" are correctly spelt anyway.

   Redaction: Jeffery, 2001jan01

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040 qmult 00200 1 1 5 easy memory: interstellar medium (ISM) defined 1
Extra keywords: CK-299,321, Sunlife

3. The interstellar medium (ISM) consists of:

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

   SUGGESTED ANSWER: (e)

   Wrong answers:
   a) As Lurch would say: "Aaaarh."

   Redaction: Jeffery, 2001jan01

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040 qmult 00310 1 4 1 easy deducto-memory: nebula defined
Extra keywords: CK-302,321, Sunlife

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.

   SUGGESTED ANSWER: (a)

   There are many kinds of nebulae: e.g., emission, dark, supernova remnant, reflection, and spiral nebulae: the last one is just a historical name since the spiral nebulae are spiral galaxies and not clouds, but before they were known to be galaxies were called nebulae because they looked like clouds to telescopic observers.

   Wrong answers:
   e) As Lurch would say: "Aaaarh."

   Redaction: Jeffery, 2001jan01

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040 qmult 00320 1 1 5 easy memory: molecular cloud and stars
Extra keywords: CK-321, Sunlife

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.

   SUGGESTED ANSWER: (e) See Se-220. The molecular clouds don't always have to be giant molecular clouds: are they usually giant molecular clouds?

   Wrong answers:
   d) Some of these critters probably do end up helping to make stars.

   Redaction: Jeffery, 2001jan01

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040 qmult 00330 2 1 5 moderate memory: molecular cloud composition
Extra keywords: CK-300, Sunlife

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.

   SUGGESTED ANSWER: (e)

   Hydrogen and helium dominate the composition of the universe and a molecular cloud should have molecules. Zeilik p. 332 confirms that the hydrogen in molecular clouds is molecular hydrogen.

   Wrong answers:
   a) Carbon dioxide is an important tracer of molecular clouds, but it is a minority species.

   Redaction: Jeffery, 2001jan01

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040 qmult 00410 3 4 1 tough deducto-memory: molecular clouds and their dust
Extra keywords: Sunlife , long question

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.

SUGGESTED ANSWER: (a) The problem discusses details that weren't and needn't be emphasized in class. But it shows who's thinking. See Se-212 and Zeilik p. 333, 337.

Wrong answers:

b) Hard radiation tends to break up molecules, whose bonds are not that robust. Thus the premise and conclusion of the answer disagree.

c) No, dust is important and molecular clouds and dust usually go together. But there can be dust without molecules and the reverse is probably true. But giant molecular clouds probably always have a lot of dust.

d) No, there arn't molecular clouds where one can see the star formation process in the visible: it seems to be always dust-shrouded.

e) Coincidences due happen, but modern science always suspects (and sometimes wrongly) that behind any seeming coincidence lies a a relationship.

Redaction: Jeffery, 2001jan01

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040 qmult 00420 2 4 3 moderate deducto-memory: molecular cloud dust described

Extra keywords: Sunlife

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.

SUGGESTED ANSWER: (c) See Zeilik p. 336–337.

Wrong answers:

a) Volatile and nonvolatile mix-up.

b) Volatile and nonvolatile mix-up. If it forms in a black hole, it doesn't get out. By the by, a scot is an archaic term for a payment or a tax derived from Scandinavian languages: it has nothing to do with laddies and lassies in kilts.

d) If it forms in a black hole, it doesn't get out.

e) This is terrestrial dust. I wonder what terrestrial dust is made of. Probably pretty various although some has to be silicates.

Redaction: Jeffery, 2001jan01

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040 qmult 00510 1 4 5 easy deducto-memory: movement on HR diagram

Extra keywords: CK-322-12

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

SUGGESTED ANSWER: (e)

Wrong answers:

a) This would change luminosity and surface temperature, but it does not happen "whenever."

Redaction: Jeffery, 2001jan01

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040 qmult 00610 2 4 1 moderate deducto-memory: star formation triggers

Extra keywords: CK-302, Sunlife

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.

SUGGESTED ANSWER: (a)

Wrong answers:

b) White dwarfs are miniscule compared to molecular clouds and would just run through them like beads of sand.

c) This is probably a pretty rare event and wouldn't compress clouds much.

e) Yes Tolkien has invaded space, but there are no white hobbits as far as I know.

Redaction: Jeffery, 2001jan01

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040 qmult 00710 2 4 2 moderate deducto-memory: free-fall molecular cloud

Extra keywords: Sunlife

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.

SUGGESTED ANSWER: (b)

Wrong answers:
e) The planetesimals are a much later stage in solar system formation.

Redaction: Jeffery, 2001jan01

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040 qmult 00720 1 4 1 easy deducto-memory: dense core defined sort of
Extra keywords: CK-303,321, Sunlife

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.

SUGGESTED ANSWER: (a)

Wrong answers:
e) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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040 qmult 00800 2 4 3 moderate deducto-memory: protostar defined
Extra keywords: CK-303 but no mention of IR part, Sunlife

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.

SUGGESTED ANSWER: (c) Se-222, gives this definition and FK-450 implicitly agrees. He calls the protostar a prestellar object, but that seems too convoluted for me. But the term is used loosely in astronomy I think.

Wrong answers:
e) A white dwarf is at the far end of stellar evolution.

Redaction: Jeffery, 2001jan01

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040 qmult 00810 2 4 5 moderate deducto-memory: protostar contraction 1
Extra keywords: FK-451 agree with this, Sunlife

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.

SUGGESTED ANSWER: (e)

Wrong answers:
a) Adding heat and contraction together should increase gas pressure.
b) The thermal energy generated by contraction and the increasing density of the gas do increase pressure, but they do not stop the contraction.

Redaction: Jeffery, 2001jan01

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040 qmult 01000 1 4 1 easy deducto memory: H II region defined
Extra keywords: CK-307,321,322-3

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.

SUGGESTED ANSWER: (a)

Wrong answers:
b) As Lurch would say: "Aaaarh."

Redaction: Jeffery, 2001jan01

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040 qmult 01500 1 4 3 easy deducto-memory: disk defined
Extra keywords: Sunlife

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

SUGGESTED ANSWER: (c)

Wrong answers:
a) Compact disks are disks, but not the right kind of disk.

Redaction: Jeffery, 2001jan01

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040 qmult 01510 2 4 2 moderate deducto-memory: disk formation frequency
Extra keywords: CK-304, Sunlife

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.

SUGGESTED ANSWER: (b)

Wrong answers:
d) It has been observed.

Redaction: Jeffery, 2001jan01

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040 qmult 01512 3 5 3 hard thinking: disk formation 1
Extra keywords: defective problem. Must get the story straight. Sunlife

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**.

e) 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 **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.

SUGGESTED ANSWER: (c)

Wrong answers:

a) Everyone knows that no matter escapes a black hole: at least not in a direct classical sense.
b) The infalling matter should heat up.
d) Not impact craters.
e) Not impact craters.

Redaction: Jeffery, 2001jan01