

**Introductory Astronomy****NAME:**

**Homework 14: Mars:** Homeworks and solutions are posted on the course web site. Homeworks are **NOT** handed in and **NOT** marked. But many homework problems ( $\sim 50\text{--}70\%$ ) 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

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

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

a) YYYesssss!    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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014 qmult 00100 1 4 1 easy deducto-memory: Mars order from Sun

2. Going outward from the Sun, Mars is the:

a) 4th planet.    b) 3rd planet.    c) 10th planet.    d) 1st planet.    e) 3rd and 5th planet.

**SUGGESTED ANSWER:** (a)

**Wrong answers:**

- b) This is Earth. Y'know: third rock from the Sun.  
 c) This is the undiscovered planet X.  
 d) This is Mercury.  
 e) Note even possible without some special assumptions.

**Redaction:** Jeffery, 2001jan01

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014 qmult 00110 1 4 4 easy deducto-memory: Mars' name

3. The planet Mars gets its name from:

a) a candy bar.    b) Cinq-Mars, a close friend of Louis XIII.    c) the Greek god of peace.  
 d) the Roman god of war.    e) Santa's chief elf.

**SUGGESTED ANSWER:** (d)

**Wrong answers:**

- a) I don't think this could possibly be true.  
 b) Louis had Cinq-Mars (Henri Coiffier Ruze D'Effiat, Marquis de Cinq-Mars 1620–1642) executed—but that doesn't mean he wasn't a close friend. Cinq-Mars even became an opera by Gounod—never cared much for opera myself—can't figure out what they are saying.  
 c) Well no:

If even one denies me, I am not.  
 The Greeks had gods for everything but me.  
 Since then  
 How could I live on earth, in heaven? Yet see  
 if you can find me in the hearts of men.

—Daniel Hoffman. (Slightly misquoted.)

- e) Stranger things have been.

**Redaction:** Jeffery, 2001jan01

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014 qmult 00200 1 4 5 easy deducto-memory: Mars discovery

4. Mars was discovered in:

a) 1610 by Galileo Galilei (1564–1642).    b) 1655 by Christiaan Huygens (1629–1695).    c) 1869 by Pietro Angelo Secchi (1818–1878).    d) 1877 by Giovanni Schiaparelli (1835–1910).    e) in prehistory by numerous persons no doubt.

**SUGGESTED ANSWER:** (e)

See <http://www.uapress.arizona.edu/online.bks/mars/contents.htm> for the history of the observation of Mars.

**Wrong answers:**

- a) Galileo in 1610 may have been the first to view Mars telescopically.
- b) 1655 was the first time Huygens observed Mars telescopically.
- c) Secchi introduced the Italian word *canale* for narrow features he saw on Mars in 1869. It was Schiaparelli who really pushed for the existence and made them widely known.
- d) In 1877, Mars was in perihelion opposition and Schiaparelli's observations of that year led him to introduce widely the idea of Martian canals.

**Redaction:** Jeffery, 2001jan01

014 qmult 00300 1 5 1 easy thinking: Martian canals

## 5. The Martian canals:

- a) were first widely introduced (but not first “discovered”) by Giovanni Schiaparelli (1835–1910) in **1877** as explanations for features he saw on Mars. His Italian word *canale* (which does not necessarily imply artificial water channel in Italian) was misleadingly translated as canal in English. Percival Lowell (1855–1916) picked up the idea of canals and believed that they proved intelligent life on Mars. He mapped out the canals in detail using his Lowell Observatory in Flagstaff, Arizona. With the probable exception of Valles Marineris, all his canals were apparently illusions: one supposes artifacts of the eye trying to see shapes in unresolvable or barely resolvable markings.
- b) were first widely introduced (but not first “discovered”) by Giovanni Schiaparelli (1835–1910) in **1877** as explanations for features he saw on Mars. His Italian word *canale* (which does not necessarily imply artificial water channel in Italian) was misleadingly translated as canal in English. Percival Lowell in **1980** picked up the idea of canals and believed that they proved intelligent life on Mars. He mapped out the canals in detail using his Lowell Observatory in Flagstaff, Arizona. Despite the recent NASA probes to Mars showing no canals, Lowell still maintains the canals are really there. Supermarket tabloids thoroughly support him and ascribe NASA's contrary findings to government cover-up.
- c) were first widely introduced (but not first “discovered”) by H.G. Wells (1866–1946) in **1898** in his book *The War of the Worlds*. In that book they were the handiwork of intelligent Martian octopuses: evolution had made the Martians all brain and fingers. Wells's son Orson Welles (1915–1985) (who had Americanized his surname) based his Mars invasion Halloween radio show of 1938, *The War of the Worlds*, on his father's book. The radio show caused considerable panic (especially in New Jersey) among people who were perhaps predisposed by various 20th century events to believe in remorseless, faceless invaders. In any case, in his later years Welles revealed that the canals had always been a hoax.
- d) are now dry, but once they carried water from the polar caps to Valles Marineris which was then a long narrow sea. Although the canals are almost certainly natural, the idea that extinct Martians built them to supply water to their cities (Martian versions of Las Vegas) is still held by some noted scientists such as Percival Lowell, Orson Welles, and Libbrecht.
- e) include the Suez, Panama, and Welland Canals.

**SUGGESTED ANSWER:** (a) This is the joke question because of the cute answers.

**Wrong answers:**

- b) This just can't be right.
- c) The date of the book may be wrong (but I got off a web site) and Orson wasn't the son of H.G., but the actual same person. See Se-478
- d) The Martians certainly would never have built a Las Vegas.
- e) No, no, and probably not. My native canal couldn't be on Mars: I would know it wouldn't; I; maybe not, but then ...

**Redaction:** Jeffery, 2001jan01

014 qmult 00310 1 4 2 easy deducto-memory: Martian seasons

## 6. Mars has seasons principally because:

- a) it is red.
- b) its axis is tilted by about 25° to the pole perpendicular to Mars' orbital plane.
- c) its orbit is super-highly elliptical.
- d) of its volcanoes.
- e) of its impact craters.

**SUGGESTED ANSWER:** (b)

Well, Ka-291 and PF-117 state that the tilt is the main cause of the seasons. I think the fairly large eccentricity of Mars' orbit must play a secondary role.

**Wrong answers:**

- a) A red herring.
- c) Well Mars eccentricity is 0.0934 which is pretty large for a planet, but you still can't say its orbit is super-highly elliptical.
- d) Nah.
- e) Nah.

**Redaction:** Jeffery, 2001jan01

014 qmult 00312 1 4 4 easy deducto-memory: Mars size

7. The Mars' diameter in units of Earth's diameter is about:

- a) 10.
- b) 5.
- c) 1.
- d) 1/2.
- e) 1/1000.

**SUGGESTED ANSWER:** (d) The accurate value is 0.5326 for equatorial diameters.

**Wrong answers:**

- a) Everyone should know Mars is significantly smaller than Earth.
- e) But Mars is not tiny compared to Earth.

**Redaction:** Jeffery, 2001jan01

014 qmult 00320 1 4 5 easy deducto-memory: Mars seasonal color variations

8. Briefly describe the seasonal color variations of one hemisphere of Mars' surface. (The basic color of Martian soil is reddish probably due to high iron oxide [rust] content).

- a) In the spring, increasing warmth causes green **PLANT LIFE** to flourish and this plant life covers much of the red soil surface. Hence a hemisphere surface becomes greener in spring. In the fall, the plant life declines and the hemisphere surface becomes redder again.
- b) In the spring, increasing warmth causes **PLANT LIFE** to change from red to green, greening the appearance of the surface of a hemisphere. In the fall, the plant life turns red again, reddening the appearance of the surface.
- c) In the spring a hemisphere's white polar cap, which extends to the **EQUATOR** in winter, retreats leaving a red soil surface. In the fall, white polar cap grows back to the equator turning the hemisphere white again.
- d) Dust storms cover some of the Martian surface with **GREEN DUST**. In the spring, apparently the winds strip away some of the dust leaving a **REDDER** soil surface. Thus a hemisphere appears greener in the winter and redder in the summer.
- e) Dust storms tend to cover Martian surfaces with **RED DUST**. In the spring, apparently the winds strip away some of the dust. Some of the underlying surface is dark rather than red, and so the surface becomes darker in appearance when the dust is blown away. The darker surface appears greenish in comparison to the overall red of the Martian surface. Thus a hemisphere appears redder in the winter and greener in the summer.

**SUGGESTED ANSWER:** (e) See Se-479, Se-482, and FMW-199.

**Wrong answers:**

- a) There is no obvious plant life on the Martian surface.
- b) There is no obvious plant life on the Martian surface.
- c) The polar caps never extend anywhere near the equator.
- d) Martian dust is red or more red than green anyway. Maybe brownish yellow. In legend it's red.

**Redaction:** Jeffery, 2001jan01

014 qmult 00330 1 4 3 easy deducto-memory: Martian geological features

9. On Mars:

- a) Valles Marineris is an alluvial plain, Olympus Mons is a dry ocean, Syrtis Major is a large canal, and Hellas Planitia is a large impact basin.

- b) Valles Marineris is a smile, Olympus Mons is a wart, Syrtis Major is a *Star Trek* character, and Hellas Planitia is a plantation.
- c) Valles Marineris is a large canyon, Olympus Mons is a large volcano, Syrtis Major is a large dark region, and Hellas Planitia is a large impact basin.
- d) Valles Marineris is a large volcano, Olympus Mons is a large canyon, Syrtis Major is a large impact basin, and Hellas Planitia is a large dark region.
- e) Valles Marineris is a large impact basin, Olympus Mons is a large dark region, Syrtis Major is a large canyon, and Hellas Planitia is a large volcano.

**SUGGESTED ANSWER:** (c) See HI-185 in particular for the Hellas Planitia impact basin.

**Wrong answers:**

- a) Well the Hellas Planitia is correctly identified.
- b) It was Marina Syrtis who was on *Star Trek*. But she never became really famous: she doesn't have an unofficial web site devoted to worshipping her.

**Redaction:** Jeffery, 2001jan01

014 qmult 00500 1 4 4 easy deducto-memory: Valles Marineris

10. Valles Marineris is a:

- a) Hibernian bog.
- b) small valley on Venus.
- c) small valley on Mars that was probably formed by a huge river, now of course completely dry.
- d) large valley on Mars that was probably formed by the Martian crust cracking and subsiding somehow.
- e) large valley on Mars that was probably formed by a long drought early in Martian history.

**SUGGESTED ANSWER:** (d)

See FMW-198, Se-483. Valles Marineris was named for one or more of the Mariner probes, but I can't find a reference for this.

**Wrong answers:**

- a) An Irish swamp. I ought to know since I may already be Irish myself.
- b) It's on Mars.
- c) Just a fact: people don't think Valles Marineris was primarily formed by water although water may have played a role in shaping the canyon (FMW-198).
- e) Droughts don't make valleys. Yes, no, maybe, probably, certainly, without a doubt, positively, nah.

**Redaction:** Jeffery, 2001jan01

014 qmult 00700 3 4 2 tough deducto-memory: Martian polar ice caps

11. The Martian polar ice caps are:

- a) possibly permanent **CARBON DIOXIDE** ice covered in winter by a layer of **WATER** ice. In the spring, the water ice layer **MELTS** and the water quickly evaporates. The carbon dioxide ice remains through the summer. Remember, at a given pressure, carbon dioxide ice **MELTS** at a higher temperature than water ice. In the fall, water vapor condenses on the polar caps again.
- b) possibly permanent **WATER** ice covered in winter by a layer of **CARBON DIOXIDE** ice. In the spring, some or all of the carbon dioxide (all at the northern cap it seems) **SUBLIMES** (i.e., passes directly to gas phase): the atmospheric pressure on Mars is too low to for a liquid carbon dioxide phase to exist. In the fall, carbon dioxide condenses on the polar caps again.
- c) possibly permanent **CARBON DIOXIDE** ice covered in winter by a layer of **WATER** ice. In the spring, the water ice **SUBLIMES** (i.e., passes directly to gas phase): the atmospheric pressure on Mars is too low to for a liquid water phase to exist. Remember, at a given pressure, carbon dioxide ice **SUBLIMES** at a higher temperature than water ice. In the fall, water vapor condenses on the polar caps again.
- d) made of whitish rock.
- e) ordinary water snow. They melt totally in the spring and then are reconstituted by large snow storms in the late fall and winter.

**SUGGESTED ANSWER:** (b)

**Wrong answers:**

- a) People don't ordinarily see carbon dioxide ice, but they do see do see water ice all the time at least in drinks in Las Vegas. They should guess that carbon dioxide ice melts at a much lower temperature than water ice. Also they could recall that liquid water doesn't.
- d) Why only whitish rock at the poles.
- e) Snow storms on Mars. Who's ever heard of that.

**Redaction:** Jeffery, 2001jan01

014 qmult 00830 2 1 3 moderate memory: rain-fed run-off channels

12. Circa 2003, analysis of dendritic channels on Mars based on Mars Global Surveyor data led to the conclusion that in some cases at least these channels were very probably:

- a) glacial melt ponds.
- b) glacial melt oceans.
- c) rain-fed run-off channels.
- d) rain-fed canals.
- e) snow-fed canals.

**SUGGESTED ANSWER:** (c) See Kerr, R. A. 2003jun06, Science, 300, 1496.

**Wrong answers:**

- d) There are no Martian canals.

**Redaction:** Jeffery, 2001jan01

014 qmult 00850 2 4 4 moderate deducto-memory: delta or distributary fan on Mars

13. "Let's play *Jeopardy!* For \$100, the answer is: The discovery in 2003 of this feature on Mars proves that at some time in the past there was continuous liquid water flow on Mars."

What is a \_\_\_\_\_, Alex?

- a) glacier
- b) tidal shoal
- c) gully
- d) river delta or distributary fan (which is closely related to, but not the same thing as, a river delta)
- e) rotary fan (which was likely a river delta)

**SUGGESTED ANSWER:** (d)

**Wrong answers:**

- e) A rotary fan is a thing that blows air at you.

**Redaction:** Jeffery, 2001jan01

014 qmult 00870 1 4 5 easy deducto-memory: flowing water on Mars

14. Why is it thought that there was once flowing liquid water on Mars?

- a) The water ice at the **POLAR CAPS** suggests this.
- b) The two kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are the **MARTIAN CANALS** which also suggest that there was once intelligent life of on Mars.
- c) The two kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are the circular channels that are concentric around large impact craters. There are usually between 3 and 7 of these circular channels. It is hypothesized that they were constructed by the **MARTIANS** in order to make dart board patterns.
- d) The two kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are are called **OUTFLOW CHANNELS OR ARROYOS**. The largest are 10 km or more in width and hundreds of kilometers long. It is hypothesized that these outflow channels were produced **TECTONIC PLATES** grinding against

each other. The liquid water in outflow channels was an inconsequential and inconspicuous later incident.

- e) The three kinds of dry channels found on Mars. The first kind are runoff-like channels which are meandering and dendritic (branchy), and are thought to have been rain-fed rivers. They are found in the old Martian highland and are perhaps older than 3.9 billion years. They are tens of meters in width and perhaps 10 to 20 km long. The second kind are called **OUTFLOW CHANNELS OR ARROYOS**. These are 10 km or more in width and hundreds of kilometers long. It is hypothesized that these outflow channels were produced by **SUDDEN, LARGE FLOODS**. The floods occurred when an impact or volcano suddenly melted a large amount of frozen water in the soil (i.e., permafrost). The **THIRD KIND** are river delta formations. These formations are considered absolute proof that there was continuous liquid water flow on Mars at some time in its history.

**SUGGESTED ANSWER:** (e) See FMW-202, Se-485, Ze-212 for the details about the channels.

**Wrong answers:**

- a) The polar caps don't prove there is liquid water now and I don't see how they can prove directly that there ever was.  
 b) The Martian canals were a delusion—well a mistake.  
 c) Ah, the sacred dart board. If you choose this answer, you've done too much quaffing in English pubs.  
 d) There is no evidence for plate tectonics on Mars. And the way the answer is worded it doesn't seem likely that the outflow channels could be proof of liquid water if the liquid water were later, inconsequential, and inconspicuous.

**Redaction:** Jeffery, 2001jan01

014 qmult 00900 2 4 5 moderate deducto-memory: Allan Hills 84001

15. "Let's play *Jeopardy!* For \$100, the answer is: NASA researchers in 1996 proposed that this object possibly contained fossilized Martian microbes."

What is \_\_\_\_\_, Alex?

- a) Pathfinder    b) Viking 1    c) Beagle 2    d) star Cary Grant 1904  
 e) meteorite Allan Hills 84001

**SUGGESTED ANSWER:** (e)

**Wrong answers:**

- d) Good old Cary Grant (1904–1986).

**Redaction:** Jeffery, 2001jan01

014 qmult 01000 1 4 2 easy deducto-memory: no Mars surface life

16. Why is life as we know it not possible (without some extreme adaptations) on the surface of present-day Mars?

- a) The surface of Mars is relatively **UNPROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. But there is, however, **PLENTY** of liquid water (which is necessary for life) in the deep bottoms craters where the atmospheric pressure is high.  
 b) First, the surface of Mars is relatively **UNPROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. Second, liquid water (which is necessary for life as we know it) **CANNOT** exist for long on the Martian surface due to the low atmospheric pressure.  
 c) First, the surface of Mars is relatively **PROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. Second, liquid water (which is necessary for life as we know it) **CANNOT** exist on the Martian surface due to the low atmospheric pressure.  
 d) First, the surface of Mars is relatively **PROTECTED** from sterilizing UV radiation because of its thin atmosphere which in particular has no UV-absorbing ozone layer. But there is, however, **PLENTY** of liquid water in the deep bottoms craters where the atmospheric pressure is high.  
 e) We've never found any life, so there isn't any.

**SUGGESTED ANSWER:** (b)

Microbial life probably cannot survive ultraviolet life without atmospheric protection or some extreme adaptation. With no microbial life it is hard to imagine other life which also is endangered by ultraviolet. Yours truly doesn't know the whole story of the ultraviolet danger to life.

**Wrong answers:**

- a) There is no liquid water in craters today: probably once there was when the atmospheric pressure was higher.
- c) Being relatively protected is an argument for the possibility of life, not an argument against it.
- e) Not really an answer to the question since it doesn't say why life isn't possible: there could be no life and life could still be possible. Well one could argue that if there is no life, no life is possible because there may have been no way for it to start. But that's getting very fine. In any case, we haven't looked hard enough to say that there is no life without buttressing the argument with reasons why life is impossible.

**Redaction:** Jeffery, 2001jan01

014 qmult 01100 2 4 4 moderate deducto-memory: Mars subsurface life

17. Life (as we know it) on Mars' surface appears impossible. It is speculated that subsurface life may exist. Why?

- a) The Viking and Pathfinder probes detected abundant traces of **ORGANIC MOLECULES** when they drilled **SEVERAL HUNDREDS** of meters below the surface. Organic molecules are necessary for life, but are not sufficient evidence of it.
- b) Below the surface the temperature is much **LOWER** and conditions much **DRYER**, and this would allow life to exist.
- c) Below the surface there may be **SUFFICIENT WARMTH** from the Mars interior to sustain life. (Mars probably still has significant though it is insufficient for very obvious geological activity.) The heat and higher subsurface pressure could allow liquid water to exist (in rock pores), and liquid water is also needed for life. Additionally, below the surface, life would be protected from ultraviolet radiation. The **LACK** of any deep crustal life (i.e., life deeper than a few meters) on Earth, however, makes the idea of subsurface life on Mars very speculative.
- d) Below the surface there may be **SUFFICIENT WARMTH** from the Mars interior to sustain life. (Mars probably still has significant though it is insufficient for very obvious geological activity.) The heat and higher subsurface pressure could allow liquid water to exist (in rock pores, etc.), and liquid water is also needed for life. Additionally, below the surface, life would be protected from ultraviolet radiation. The **PRESENCE** of deep crustal life (i.e., life to down to perhaps a few kilometers: i.e., a deep biosphere) on Earth lends credence to the idea of subsurface Martian life. In fact, some people now wonder if subsurface life may be the commonest form of life in the Universe.
- e) The exo-biology people will grasp at any straw.

**SUGGESTED ANSWER:** (d)

See HI-194–196. But the difference between (c) and (d) is not so great, but it's crucial.

**Wrong answers:**

- a) FMW-203 says the Viking probes found no organic molecules and that the UV radiation would probably have destroyed any near the surface. I assume Pathfinder also drew a blank. Neither probe could have drilled hundreds of meters, but it would have been interesting if they could have.
- b) Colder and dryer would be worse for life.
- c) There is a deep biosphere on Earth.
- e) The joke answer. Arguably true, but obviously just an opinion and not mine either.

**Redaction:** Jeffery, 2001jan01

014 qmult 03200 1 4 3 easy deducto-memory: Mars moon shapes

18. Why are Mars' moons Phobos and Deimos so nonspherical?

- a) Excessive cratering constantly stops the "spherizing" effect of gravity.
- b) Volcanic effects continually distort their shapes.



- c) Their mass is small, and thus their self-gravity is insufficient to force them to be spherical by overcoming the structural electromagnetic forces of their material and, perhaps, their centrifugal force due to their rotation.
- d) Their mass is small, and thus their self-gravity is insufficient to force them to be spherical against the effect of the solar wind.
- e) The tidal force of Mars has pulled them into football shapes.

**SUGGESTED ANSWER:** (c)

**Wrong answers:**

- a) Gravity isn't sufficient to spherize even if they weren't sometimes impacted. It is true that micrometeoritic impacts (with all other) effects turned off might reduce the Moons to spherical someday. But gravity can't alone spherize them.
- b) Volcanism on a tiny old planetesimal!
- d) The old solar wind red herring. Wrong answers are so easily made up using it. Of course, it really does do some things.
- e) The tidal force would conceivable force them into football shape if it were strong enough. They aren't really football shape of of course, but irregular.

**Redaction:** Jeffery, 2001jan01

014 qmult 03300 2 5 3 moderate thinking: Mars moons tidally locked

19. Mars' moons Phobos and Deimos are small, nonspherical bodies with triaxial dimensions in kilometers of about  $27 \times 21.6 \times 18.8$  and  $15 \times 12.2 \times 11$ , respectively. Their mean distances from Mars center are 2.761 and 6.906 Mars radii (1.470 and 3.678 Earth radii). Their eccentricities are 0.015 and 0.0005. Their orbital periods and rotational periods are the same length: the periods for Phobos are 0.31891023 days and for Deimos are 1.2624407 days. They both orbit eastward. Because Phobos' orbital period is shorter than Mars' rotational period (1.02595675 days), Phobos rises west and sets east. Deimos rises east and sets west, but moves relatively slowly across the sky relative to a local sky coordinate system. The moons are probably captured asteroids. The exact sameness (on average) of moons's orbital and rotational periods shows that they are tidally locked to Mars. Why would this be expected?

- a) Because of the strength of the solar wind.
- b) They are close to Mars, and so Mars' tidal force is probably quite **STRONG**. Moreover, their small size meant that they probably had **INCREDIBLY HUGE ROTATIONAL KINETIC ENERGY** when they started orbiting Mars. The **MORE** the initial rotational kinetic energy, the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. Thus their probably huge initial rotational kinetic energy also helped tidal locking to occur.
- c) They are close to Mars, and so Mars' tidal force is probably quite **STRONG**. Moreover, their small size meant that they probably had **LOW ROTATIONAL KINETIC ENERGY** when they started orbiting Mars, unless they were rotating incredibly quickly. The **LOWER** the initial rotational kinetic energy (provided it was greater than needed for tidally locking), the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. If they had insufficient initial rotational kinetic energy for tidal locking, the Martian tidal force would have had to speed them up: but since they are small bodies, that added amount of rotational kinetic energy was probably relatively small. Thus because of their small size, it was probably relatively easy to change their rotational kinetic energy to just the amount needed for tidal locking.
- d) They are close to Mars, and so Mars' tidal force is probably quite **WEAK**. Moreover, their small size meant that they probably had **INCREDIBLY HUGE ROTATIONAL KINETIC ENERGY** when they started orbiting Mars. The **MORE** the initial rotational kinetic energy, the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. Thus their probably huge initial rotational kinetic energy also helped tidal locking to occur.
- e) They are close to Mars, and so Mars' tidal force is probably quite **WEAK**. Moreover, their small size meant that they probably had **LOW ROTATIONAL KINETIC ENERGY** when they started orbiting Mars, unless they were rotating incredibly quickly. The **LOWER** the initial rotational kinetic energy (provided it was greater than needed for tidally locking), the easier it was to get rid of enough of it to have slowed them down to the tidally locked situation. If they had insufficient initial rotational kinetic energy for tidal locking, the Martian tidal force would have had to speed them up: but since they are small bodies, that added amount of rotational kinetic energy

was probably relatively small. Thus because of their small size, it was probably relatively easy to change their rotational kinetic energy to just the amount needed for tidal locking.

**SUGGESTED ANSWER:** (c)

Yes, Phobos and Deimos have synchronous orbital and rotational periods (Cox-307). Note the reasoning is all plausible, not conclusive. It's based on general ideas about how things in the Solar System are arranged in terms of relative amounts of rotational kinetic energy and strengths of tidal forces. It wouldn't take a lot of work though to investigate the problem mathematically, but that is well beyond the scope of this class (and beyond any interest of mine at the moment).

**Wrong answers:**

- a) An irrelevant red herring.
- b) Nothing rules out huge initial rotational kinetic energy, but it doesn't seem likely. In any case the larger the rotational kinetic energy, the longer it would take for the tidal force to effect tidal locking.
- d) See (b). Also the tidal force is probably quite strong. But really the student doesn't know this. But the student knows the stronger the tidal force, the easier it is to effect tidal locking. And the question asks why we would expect tidal locking. Actually the tidal force scales as  $(M_{\text{centralbody}}/d^3)r$  (French p. 533). Mars is 1/11 of the Earth Mass, the distance  $d$  to Deimos is about 1/16 of the Earth-Moon distance, and  $r$  (the Deimos radius is about 1/300 of the Moon's radius. Thus the tidal force of Mars on Deimos is of order  $(1/11)(1/300)/(1/16)^3 = 4000/3300 = 1$  of the Earth's on the Moon. Since Deimos had very probably much less kinetic energy than the Moon, tidal locking probably happened much faster than in the case of the Moon.
- e) See (d)

**Redaction:** Jeffery, 2001jan01