ASTR 101
Homework 1 Solutions

Does It Make Sense? *Decide whether the statement makes sense (or is clearly true) or does not make sense (or is clearly false). Explain clearly; not all of these have definitive answers, so your explanation is more important than your chosen answer.*

1-13 *Our solar system is bigger than some galaxies.* The statement is clearly false (*0.5pt*). Galaxies are hundreds of thousands of light years across, while the solar system is only a fraction of a light year across. Furthermore, galaxies contain billions of stars. The Milky Way alone contains over 100 billion stars. Our solar system, however, only contains one star. Therefore, we can't be larger than some galaxies because we're only a tiny part of one. Consider the image below. On the right-hand side of the image is just a tiny fraction of the Milky Way galaxy as seen from Earth. (*0.5pt*).

1-14 *The universe is billions of light-years in age.* The statement does not make sense (*0.5pt*), because a light year is a unit of distance, not a unit of time. The Universe is billions of *years* in age and billions of *light years* across (*0.5pt*).

1-16 *Someday we may build spaceships capable of traveling a light-year in only a decade.* The statement makes sense (*0.5pt*). Light takes a year to travel 9.461×10^{12} km, aka a light year. Since we would travel slower than light, it makes sense to say that in the future we could travel that distance in a decade. We can actually calculate how fast this spaceship would need to be in order to cover this distance in a decade:

$$\begin{aligned} v &= \frac{d}{t} \\ &= \frac{9.461 \times 10^{12}\,\mathrm{km}}{10\,\mathrm{yr} \times \frac{365\,\mathrm{d}}{1\,\mathrm{yr}} \times \frac{24\,\mathrm{h}}{1\,\mathrm{d}} \times \frac{60\,\mathrm{min}}{1\,\mathrm{h}} \times \frac{60\,\mathrm{s}}{1\,\mathrm{min}}} \\ &= 29\,980\,\mathrm{km\,s^{-1}}. \end{aligned}$$

We certainly don't have any spacecraft currently that travels this fast! (*0.5pt*)

1-17 *Astronomers recently discovered a moon that does not orbit a planet.* The statement does not make sense (*0.5pt*). Moons always orbit a planet. If they didn't, they'd be considered dwarf planets or asteroids (*0.5pt*).

1-18 *NASA will soon launch a spaceship that will photograph our Milky Way Galaxy from beyond its halo.* The statement does not make sense (*0.5pt*). For a satellite to take pictures of our galaxy from "beyond the halo," it would have to leave the galaxy. It would take millions of years to reach that far, which at that point humans might have gone extinct. Even if we were still around, it would take then thousands of years for the signal to come back to us (*0.5pt*).

1-42 Spacecraft Communication *We use radio waves, which travel at the speed of light, to communicate with robotic spacecraft. How long does it take a message to travel from Earth to a spacecraft at (a) Mars at its closest to Earth (about 56 million km)? (b) mars at its farthest from Earth (about 400 million km)? (c) Pluto at its average distance from Earth (about 5.9 billion km)?*

The speed of light, c, is $300\,000\,\mathrm{km\,s^{-1}}$.

(a) The time it takes for a radio message to travel from Earth to Mars at its closest distance $d = 56\,000\,000\,\mathrm{km}$ is

$$\begin{aligned} v &= \frac{d}{t} \\ t &= \frac{d}{c} \\ &= \frac{56\,000\,000\,\mathrm{km}}{300\,000\,\mathrm{km\,s^{-1}}} \\ &= 186.667\,\mathrm{s} \\ &= 3.111\,\mathrm{min.} \end{aligned}$$

(b) The time it takes for a radio message to travel from Earth to Mars at its furthest distance $d = 400\,000\,000\,\mathrm{km}$ is

$$\begin{aligned} t &= \frac{d}{c} \\ &= \frac{400\,000\,000\,\mathrm{km}}{300\,000\,\mathrm{km\,s^{-1}}} \\ &= 1333\,\mathrm{s} \\ &= 22.22\,\mathrm{min.} \end{aligned}$$

(c) The time it takes for a radio message to travel from Earth to Pluto at its average

distance $d = 5\,900\,000\,000\,\mathrm{km}$ is

$$\begin{aligned} t &= \frac{d}{c} \\ &= \frac{5\,900\,000\,000\,\mathrm{km}}{300\,000\,\mathrm{km\,s^{-1}}} \\ &= 19\,667\,\mathrm{s} \\ &= 327.8\,\mathrm{min} \\ &= 5.463\,\mathrm{h}. \end{aligned}$$

1-46 Driving Tips *Imagine that you could drive your car at a constant speed of 100 km h^{-1} (62 mi h^{-1}), even across oceans and in space. (In reality, the law of gravity would make driving through space at a constant speed all but impossible.) How long would it take to drive (a) around Earth's equator? (b) from the Sun to Earth? (c) from the Sun to Pluto? (d) to Alpha Centauri?*

You are driving at a constant speed of $v = 100\,\mathrm{km\,h^{-1}}$.

(a) The Earth's equator has a circumference of

$$C = 2\pi R_E = 2\pi(6400\,\mathrm{km}) = 40\,212\,\mathrm{km}.$$

The time it would take you to drive around the Earth's equator is

$$\begin{aligned} t &= \frac{d}{v} \\ &= \frac{40\,212\,\mathrm{km}}{100\,\mathrm{km\,h^{-1}}} \\ &= 402.1\,\mathrm{h} \\ &= 16.76\,\mathrm{d}. \end{aligned}$$

(b) The distance from the Earth to the Sun is $1\,\mathrm{AU} = 150\,000\,000\,\mathrm{km}$. The time it would take you to drive from the Sun to the Earth is

$$\begin{aligned} t &= \frac{d}{v} \\ &= \frac{150\,000\,000\,\mathrm{km}}{100\,\mathrm{km\,h^{-1}}} \\ &= 1\,500\,000\,\mathrm{h} \\ &= 62\,500\,\mathrm{d} \\ &= 171.1\,\mathrm{yr}. \end{aligned}$$

(c) The distance from the Sun to Pluto is 39.48 AU = 5 906 100 000 km (see APPENDIX E). The time it would take you to drive from the Sun to Pluto is

$$\begin{aligned} t &= \frac{d}{v} \\ &= \frac{5\,906\,100\,000\,\mathrm{km}}{100\,\mathrm{km\,h^{-1}}} \\ &= 59\,061\,000\,\mathrm{h} \\ &= 6738\,\mathrm{yr}. \end{aligned}$$

(d) The distance from the Sun to Alpha Centauri is $4.4\,\mathrm{ly} = 4.16 \times 10^{13}\,\mathrm{km}$ (see p. 8). The time it would take you to drive from the Sun to Alpha Centauri is

$$\begin{aligned} t &= \frac{d}{v} \\ &= \frac{4.16 \times 10^{13}\,\mathrm{km}}{100\,\mathrm{km\,s^{-1}}} \\ &= 4.16 \times 10^{11}\,\mathrm{h} \\ &= 4.746 \times 10^{7}\,\mathrm{yr}. \end{aligned}$$

DOES IT MAKE SENSE? *Decide whether the statement makes sense (or is clearly true) or does not make sense (or is clearly false). Explain clearly; not all of these have definitive answers, so your explanation is more important than your chosen answer.*

2-17 *The constellation Orion didn't exist when my grandfather was a child.* The statement does not make sense (*0.5pt*). Although the constellations were formally accepted by the International Astronomical Union in 1928, that's not when the constellations themselves were "invented." The constellations' positions in the sky change as the seasons do on Earth, and to a lesser extent, as the Earth's axis precesses. However, that arrangement has been there for thousands of years, and will continue to be so (*0.5pt*).

2-19 *Last night the Moon was so big that it stretched for a mile across the sky.* The statement does not make sense (*0.5pt*). The Moon does not change size, it only gets closer or further away from Earth in its orbit. Even that movement is not enough to make the Moon appear to stretch "a mile across the sky." We don't measure things in miles on the sky anyway; we see them in angular units, such as degrees, arcminutes, and arcseconds (*0.5pt*).

2-22 *Last night I saw Mars move westward through the sky in its apparent retrograde motion.* The statement does not make sense (*0.5pt*). Mars does move in retrograde. However, be aware that you can't see it complete its retrograde motion over one night; it takes several weeks to see it.

2-24 *If Earth's orbit were a perfect circle, we would not have seasons.* The statement is clearly false (*0.5pt*). Earth's seasons are not controlled by how far away we are from the Sun, but rather by the tilt of the Earth's axis. In face, we are closest to the Sun around January 3 and furthest away around July 4 (*0.5pt*).

2-26 *This morning I saw the full moon setting at about the same time the Sun was rising.* This statement is clearly true (*0.5pt*). Full moons can only occur when the Moon is on the opposite side of the Earth from the Sun. Therefore, as the Sun rises/sets, the full moon is setting/rising (*0.5pt*).

2-40 New Planet *A planet in another solar system has a circular orbit and an axis tilt of 35°. Would you expect this planet to have seasons? If so, would you expect them to be more extreme than the seasons on Earth? If not, why not?*

Yes, we would expect the planet to have seasons, because seasons are controlled by the axial tilt of the planet, not by its distance to its host star. It would have more extreme seasons than Earth, because it has a higher axial tilt than Earth's 22.5° tilt.

2-53 Find the Sun's Diameter *The Sun has an angular diameter of about 0.5° and an average distance of about 150 million km. What is the Sun's approximate physical diameter? Compare your answer to the actual value of 1 390 000 km.*

Given that the Sun has an angular diameter of about 0.5° and an average distance of about 150 million kilometers, we can use the angular diameter equation from Mathematical Insight 2.1:

$$\theta = d \times \frac{360^\circ}{2\pi D},$$

where θ is the angular diameter, d is the physical diameter, and D is the physical distance. Therefore,

$$\begin{aligned}
\theta &= d \times \frac{360^\circ}{2\pi D} \\
d &= \theta \times \frac{2\pi D}{360^\circ} \\
&= 0.5^\circ \times \frac{2\pi(150\,000\,000\,\mathrm{km})}{360^\circ} \\
&= 1\,310\,000\,\mathrm{km}.
\end{aligned}$$

This is the Sun's approximate diameter. This is smaller than the Sun's actual diameter of 1 390 000 km by about 5.7%.

Extra Credit

2-55 Eclipse Conditions *The Moon's precise equatorial diameter is 3476 km, and its orbital distance from Earth varies between 356 400 and 406 700 km. The Sun's diameter*

is 1 390 000 km, and its distance from Earth ranges between 147.5 and 152.6 million km. (a) Find the Moon's angular size at its minimum and maximum distances from Earth. (b) Find the Sun's angular size at its minimum and maximum distances from Earth. (c) Based on your answers to parts (a) and (b), is it possible to have a total solar eclipse when the Moon and Sun are both at their maximum distance? Explain.

We have the angular diameter equation from above, and all the distances and sizes that we need.

(a) The Moon's angular size at its minimum distance is

$$\begin{aligned}\theta &= d \times \frac{360^\circ}{2\pi D} \\ &= 3476\,\text{km} \times \frac{360^\circ}{2\pi(356\,400\,\text{km})} \\ &= 0.559^\circ.\end{aligned}$$

The Moon's angular size at its maximum distance is

$$\begin{aligned}\theta &= d \times \frac{360^\circ}{2\pi D} \\ &= 3476\,\text{km} \times \frac{360^\circ}{2\pi(406\,700\,\text{km})} \\ &= 0.49^\circ.\end{aligned}$$

(b) The Sun's angular size at its minimum distance is

$$\begin{aligned}\theta &= d \times \frac{360^\circ}{2\pi D} \\ &= 1\,390\,000\,\text{km} \times \frac{360^\circ}{2\pi(147\,500\,000\,\text{km})} \\ &= 0.54^\circ.\end{aligned}$$

The Sun's angular size at its maximum distance is

$$\begin{aligned}\theta &= d \times \frac{360^\circ}{2\pi D} \\ &= 1\,390\,000\,\text{km} \times \frac{360^\circ}{2\pi(152\,600\,000\,\text{km})} \\ &= 0.522^\circ.\end{aligned}$$

(c) When the Moon is at its maximum distance, its angular size is 0.49°. The Sun's angular size at its maximum distance is 0.522°. Since these two are slightly different, there will not be a total solar eclipse. Instead it will be an annular or partial solar eclipse.