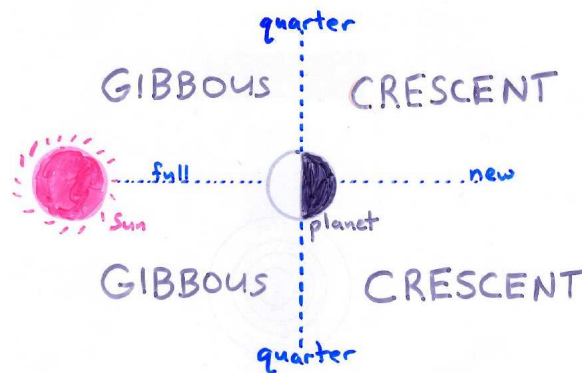


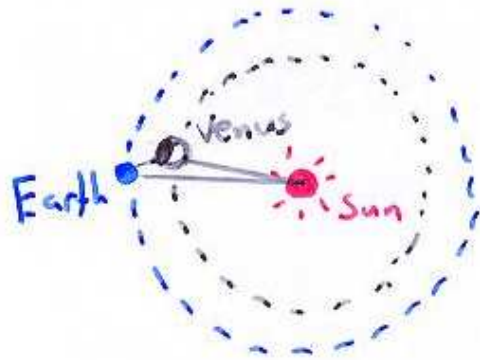
ASTRONOMY 294Z: The History of the Universe
Professor Barbara Ryden

SOLUTIONS TO PROBLEM SET # 2

1) [20 points] *With a telescope here on Earth, would we ever see Venus in a crescent phase? If so, sketch the relative positions of Venus, Sun, and Earth when that happens.*



To clarify the conditions under which a planet (or moon) appears as a crescent, I drew the above diagram. The planet is brightly illuminated on the hemisphere facing the Sun, and dark on the hemisphere away from the Sun. To see only the dark hemisphere (called the “new” phase), an observer must be along the dotted line labeled “new”. To see only the bright hemisphere (called the “full” phase), an observer must be along the dotted line labeled “full”. To see the planet half dark and half light, (called “first quarter” or “last quarter”), an observer must be along the dotted lines labeled “quarter”. To see the gibbous phase (mostly bright, with a little slice of dark), the observer must be in one of the two quadrants labeled “GIBBOUS”. Finally, to see the planet in its crescent phase (mostly dark, with a little slice of bright), the observer must be in one of the two quadrants labeled “CRESCENT”. **To see a planet in its crescent phase, the observer must be farther from the Sun than the observed planet is.** Since the Earth is farther from the Sun than Venus is, it is possible to see Venus in a crescent phase from the Earth. A diagram showing a configuration in which Venus would be a crescent is shown at the top of the next page.



2) [20 points] *With a telescope here on Earth, would we ever see Mars in a crescent phase? If so, sketch the relative positions of Mars, Sun, and Earth when that happens.*

As discussed in the solution to problem 1, we can only see a planet as a crescent when it's closer to the Sun than we are. Since Mars is always farther from the Sun than the Earth is, we **never** see Mars in a crescent phase.

3) [20 points] *How long does it take light to travel from the Sun to the Earth? The Sun's nearest neighbor among the stars, a dim little star called Proxima Centauri, is at a distance of 1.295 parsecs from us. How long does it take light to travel from Proxima Centauri to the Earth?*

The average distance from the Sun to the Earth is $d = 1 \text{ AU} = 1.5 \times 10^{11} \text{ meters} = 1.5 \times 10^8 \text{ kilometers}$. The speed of light is $c = 3 \times 10^8 \text{ meters/sec} = 300,000 \text{ kilometers/sec}$. The time it takes light to travel from the Sun to the Earth is thus

$$t = \frac{d}{c} = \frac{1.5 \times 10^{11} \text{ meters}}{3 \times 10^8 \text{ meters/sec}} = 500 \text{ seconds} . \quad (1)$$

In other words, it takes light 8 minutes and 20 seconds to reach the Earth from the Sun.

The distance from Proxima Centauri to the Sun is

$$d_{\text{prox}} = 1.295 \text{ parsecs} \times \frac{206,000 \text{ AU}}{1 \text{ pc}} \times \frac{1.5 \times 10^{11} \text{ meters}}{1 \text{ AU}} = 4.00 \times 10^{16} \text{ meters} . \quad (2)$$

Thus, the time it takes light to travel from Proxima Centauri to the Sun is

$$t_{\text{prox}} = \frac{d_{\text{prox}}}{c} = \frac{4.00 \times 10^{16} \text{ meters}}{3 \times 10^8 \text{ meters/sec}} = 1.33 \times 10^8 \text{ sec} . \quad (3)$$

This length of time can also be written as $2.22 \times 10^6 \text{ min}$, or as 37,100 hr, or as 1540 days, or as 4.23 years. (The travel time to the *Earth*, rather than the Sun, can differ from the number by as much as 8 minutes and 20 seconds, depending on where the Earth is on its orbit relative to Proxima Centauri.)

4) [20 points] *The Voyager 1 spacecraft is presently 105.1 astronomical units from the Sun, and is moving away from the Sun at a speed of 17,200 meters per second. If it were traveling directly toward Proxima Centauri, and maintained its present speed for the entire journey, how long would it take to reach Proxima Centauri?*

The distance from the Sun to Proxima Centauri is $d_{\text{prox}} = 4.00 \times 10^{16}$ meters, as we computed in the previous problem. The distance from the Sun to Voyager 1 is $d_{\text{voy}} = 105.1 \text{ AU} \times (1.5 \times 10^{11} \text{ meters}/1 \text{ AU}) = 1.58 \times 10^{13}$ meters. This means that Voyager 1 has traveled only 0.04% of the distance to Proxima Centauri, and we can write the distance from Voyager 1 to Proxima Centauri as

$$d = d_{\text{prox}} - d_{\text{voy}} = 4.00 \times 10^{16} \text{ meters} . \quad (4)$$

For Voyager 1 to complete a journey to Proxima Centauri at its present speed would require a time

$$t = \frac{d}{v} = \frac{4.00 \times 10^{16} \text{ meters}}{1.72 \times 10^4 \text{ meters/sec}} = 2.33 \times 10^{12} \text{ sec} . \quad (5)$$

Expressed in years, the travel time is

$$t = 2.33 \times 10^{12} \text{ sec} \times \frac{1 \text{ year}}{3.2 \times 10^7 \text{ sec}} = 74,000 \text{ years} , \quad (6)$$

give or take a few centuries.

5) [20 points] *Given the answer to the previous problem, it is your opinion that manned space travel is possible with present technology? Mention at least two of the problems that interstellar travelers would face, and briefly discuss how they could be resolved.*

My opinion, which may differ from yours, is that manned interstellar travel is not presently feasible. One problem, if we launched a rocket that traveled at the speed of Voyager 1, is that the travel time to even the nearest star would be a thousand times longer than the average lifetime of a human being. This would require putting the astronauts in suspended animation (something that hasn't been successfully done with humans), or sending out a "colony ship", in which a few thousand generations of people would live and die before reaching the target star. Since packing 74,000 years of box lunches would not be practical (far too massive), the colony ship would have to be a self-sustaining ecosystem. Previous attempts to set up enclosed ecosystems have revealed the difficulty of keeping such a system from "crashing" within a few years. We have to understand the biosphere here on Earth much better if we are to recreate a mini-Earth within a spacecraft.

We might try to decrease the travel time by accelerating our interstellar spacecraft to speeds much higher than that of Voyager 1. The problem with this approach is that it requires very large amounts of energy. Moreover, even if you increased the spacecraft's speed by a factor of 100 over that of Voyager 1, it would still take 740 years to reach Proxima Centauri. Our society is evolving rapidly; are we willing to trust that future generations on the spaceship are still interested in traveling to Proxima Centauri and that future generations on Earth will still be interested in the news from Proxima Centauri?