**EXAM #2 …. ANSWERS**
**ASTR 1101-001, Spring 2008**

1. In Copernicus's heliocentric model of the universe, which of the following astronomical objects was placed in an orbit around the Earth?

   **ANSWER**. The Moon

2. In his geocentric model of the universe, Ptolemy included 'epicycles' and the concept of 'epicyclic motion' of the planets principally to explain why …

   **ANSWER**. The planets Mars, Jupiter, and Saturn occasionally exhibit retrograde motion across the sky

3. In Ptolemy's geocentric model of the universe, how long does it take the sun to complete one "orbit" around the Earth?

   **ANSWER**. 24 hours

4. In Copernicus's heliocentric model, how long does it take the stars (that are fixed on the celestial sphere) to complete one "orbit" around the Earth?

   **ANSWER**. The stars do not orbit the Earth in Copernicus's heliocentric model

5. How does Copernicus's heliocentric model explain the fact that the planet Venus never wanders very far (in angular separation) from the Sun?

   **ANSWER**. Venus orbits the Sun, but in an orbit whose size is smaller than the Earth's orbit

6. [Worth 2 problems.] *Briefly* describe three astronomical discoveries that were made by Galileo with the aid of a telescope:

   **Some acceptable ANSWERS**:

   A. Sunspots________________________________________
   B. Craters and Mountains on the Moon ____________

   C. "Moons" orbiting Jupiter ______________________
   D. Rings around Saturn ______________________

   E. Phases of Venus ____________________________
   ___________________________________________

7. Suppose that, on September 1 of 2008, you observe a planet rising in the east at sunset, then you observe this same Sun-Earth-planet alignment 15 months later, on December 1 of 2009. What is the synodic period of this planet's orbit?

**ANSWER.** 15 months

8. Suppose that, on September 1 of 2008, you observe a planet rising in the east at sunset, then you observe this same Sun-Earth-planet alignment 15 months later, on December 1 of 2009. What is the sidereal period of this planet's orbit?

**ANSWER.** 5 years

$$
\begin{aligned}
\frac{1}{B} &= \frac{1}{P_{\text{short}}} - \frac{1}{P_{\text{long}}} \\
B = \text{ synodic period} &= 15 \text{ months} \\
P_{\text{short}} = P_{\text{Earth}} &= 1 \text{ year} = 12 \text{ months} \\
\frac{1}{P_{\text{long}}} &= \frac{1}{P_{\text{short}}} - \frac{1}{B} = \frac{1}{12} - \frac{1}{15} = 0.08333 - 0.066667 = 0.016667 \\
\Rightarrow \quad P_{\text{long}} &= \frac{1}{0.016667} = 60 \text{ months} = 5 \text{ years}
\end{aligned}
$$

9. How much time passes between identical linear alignments of two planets and the Sun if the sidereal orbital periods of the two planets are 1 year and 5 years?

**ANSWER.** 15 months. (This is just the inverse of the previous problem!)

$$
\begin{aligned}
\frac{1}{B} &= \frac{1}{P_{\text{short}}} - \frac{1}{P_{\text{long}}} = \frac{1}{12} - \frac{1}{60} = 0.066667 \\
\Rightarrow \quad B &= \frac{1}{0.066667} = 15 \text{ months}
\end{aligned}
$$

10. Suppose a planet is discovered orbiting the Sun with an orbital period of 1000 years. What is the semi-major axis of this planet's orbit?

**ANSWER.** 100 AU

$$
\begin{aligned}
P^2 &= a^3 \\
\Rightarrow \quad a &= [P^2]^{1/3} = [(1000)^2]^{1/3} = [1,000,000]^{1/3} = 100 \text{ AU}
\end{aligned}
$$

11. The space shuttle orbits the Earth once every 90 minutes in a circular orbit whose radius is approximately 1 $R_{\oplus}$. What is the radius of the orbit of a geosynchronous satellite?

**ANSWER.** First you have to realize that a 'geosynchronous' satellite is one that orbits the Earth with a period of 24 hours. Then Kepler's 3rd law applied to objects orbiting the Earth gives r = 6.35 $R_{\oplus}$.

$$
\begin{aligned}
\left(\frac{r_1}{r_2}\right)^3 &= \left(\frac{P_1}{P_2}\right)^2 \\
\Rightarrow \quad \left(\frac{r_{\text{geosynchronous}}}{r_{\text{Shuttle}}}\right)^3 &= \left(\frac{P_{\text{geosynchronous}}}{P_{\text{Shuttle}}}\right)^2 \\
\Rightarrow \quad \left(\frac{r_{\text{geosynchronous}}}{1R_{\oplus}}\right)^3 &= \left(\frac{24}{1.5}\right)^2 = (16)^2 = 256 \\
\Rightarrow \quad r_{\text{geosynchronous}} &= (256)^{1/3}R_{\oplus} = 6.35R_{\oplus}
\end{aligned}
$$

12. Suppose the time that it takes you to drive a distance d = 300 miles is t = 5 hours. What is your average speed of travel?

**ANSWER.** v = d/t = 300 miles/5 hours = 60 mph

13. Suppose you drive along a road that marks the outer edge of a circular field of sugarcane. If the sugarcane field has a radius r = 5 mile and it takes you t = 60 minutes to drive all the way around the field, what is your average speed of travel?

**ANSWER.** v = d/t = (2πr)/t = 10π miles/1 hour = 10π mph = 31.4 mph

14. The planet Jupiter orbits the Sun in a nearly circular orbit whose radius is r = 5.2 AU. According to Kepler's 3rd Law of planetary motion, what is Jupiter's orbital period?

**ANSWER.** 11.9 years. (Use same approach as in Problem #10, but solve for the orbital period instead of the semi-major axis of the orbit.)

15. The steering wheel of your car can be thought of as an accelerator because __________

**ANSWER.** ___acceleration means "change in velocity"; velocity is specified by the *direction* of motion, not just the speed of motion; hence simply changing the direction of a car's motion is a form of acceleration.____

**Suppose two planets ('puppy' and 'cat') are discovered orbiting in circular orbits about another star and their measured orbital periods are 1 year (puppy) and 3 years (cat). Answer the <u>next three questions</u> based on this information.**

16. Which planet has the larger/smaller orbit?

**ANSWER**. The planet 'puppy' has the smaller orbit. (Application of Kepler's $3^{rd}$ Law.)

17. Which planet moves along its orbit at the faster/slower speed?

**ANSWER**. The planet 'cat' moves at a slower speed than 'puppy'.

18. **MOST CONFUSING PROBLEM!** Suppose on January 1, 2009 these two planets are aligned with the star about which they orbit. In what future month will the two planets first come back into this identical alignment?

**ANSWER**. This question is essentially asking you what the "synodic period" of these two planets would be. Hence, I expected you to use the 'beat period' formula and calculate a 'time between alignment' of 1.5 years = 18 months. Note that 18 months after January 1, 2009 is July 1, 2010.

**NASA has launched a spacecraft into an elliptical orbit about the sun with the following properties: At the point along its orbit where it is closest to the Sun (perihelion) the spacecraft is 1 AU from the Sun; at the point along its orbit where it is farthest from the Sun (aphelion) the spacecraft is 7 AU from the Sun. Answer the <u>next three questions</u> based on this information.**

19. What is the length of the semi-major axis of the spacecraft's elliptical orbit?

**ANSWER**. 4 AU. [The length of the major axis of the orbit is (7 AU + 1 AU) = 8 AU. Hence, the semi-major axis is one-half this length.]

20. What is the orbital period of this spacecraft?

**ANSWER**. 8 years. [Use Kepler's $3^{rd}$ law.]

21. At what position along its orbit will the spacecraft be moving the fastest?

**ANSWER**. At its perihelion position. (This is explained by Kepler's $2^{nd}$ Law.)

22. [Worth 3 problems.] Suppose NASA wants to place four spacecraft in circular orbits around the Earth with the four separate orbital periods listed in **Table 1**. What would the radius of each orbit be? (Fill in the right-hand column of **Table 1**; express the radii in units of the Earth's radius $R_{\oplus}$).

**ANSWER**. Here I expected you to use the same application of Kepler's 3rd Law (applied to objects orbiting the Earth) as in Problem #11. In fact, two of the requested answers (EH-2 and EH-4) are identical to the "geosynchronous satellite" result for Problem #11. The third object (orbital period of 30 days) is orbiting the Earth at approximately the same distance as the Moon.

## Table 1

| **Spacecrafts orbiting Earth** | **P** | **r** ($R_{\oplus}$) |
|---|---|---|
| EH-1 | 1.5 hours | 1.00 |
| EH-2 | 24 hours | 6.35 |
| EH-4 | 1 day | 6.35 |
| EH-5 | 30 days | 61.3 |

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**Potentially Useful Relations**

1 AU = $1.5 \times 10^{11}$ meters
1 year = $3.156 \times 10^{7}$ seconds
$\pi = 3.14159$
1 m/s = 2.2 mph
$R_{\oplus}$ = 6400 km
For circular orbits: $v = (2\pi r)/P$
Circumference of a circle = $2\pi r$
Kepler's 3rd Law: $P^2 = a^3$