

NAME: _____

Section Number: _____

Homework 8: Meteors, Comets and Asteroids Solutions

Due: in your section on **the week of March 31st**. Please, be neat and concise, show your work, and remember units. An answer without the correct units is wrong.

Suggested reading: Lecture notes 22, 23 and 24, and chapters 12.1, 12.2, 12.4.

1. Asteroid Spin

1a. [4 points] How fast (turns s^{-1}) must a spherical, 1km diameter asteroid, with a uniform density of 3 gm cm^{-3} , have to spin so that a person standing on the surface would *just* fly off? Included are some useful equations:

$$\left(\frac{2\pi r}{T}\right)^2 / r - \frac{GM}{r^2} = 0 = f_{\text{centripital}} - f_{\text{gravity}} \quad M_{\text{sphere}} = \text{Density} * \text{Volume}$$

Where T is the spin period in units of s .

First, let's rearrange the above for the inverse of the spin period.

$$\frac{1}{T} = \frac{1}{2\pi} \sqrt{\frac{GM}{r^3}}$$

The next piece we need is the mass of the asteroid. This is:

$$M = (3 \text{ gm cm}^{-3}) \left(\frac{4}{3} \pi (0.5 \text{ km} * \frac{10^5 \text{ cm}}{1 \text{ km}})^3 \right) = 1.57 * 10^{15} \text{ gm}$$

Finally, we plug everything into the angular speed expression and get:

$$\frac{1}{T} = \frac{1}{2\pi} \sqrt{\frac{(6.67 * 10^{-8} \text{ cm}^3 \text{ kg}^{-1} \text{ s}^{-2})(1.57 * 10^{15} \text{ gm})}{(0.5 \text{ km} * 10^5 \frac{\text{cm}}{\text{km}})^3}} = 1.4 * 10^{-4} \text{ s} = 0.52 \text{ hr}^{-1} \Rightarrow T = 1.91 \text{ hr}$$

1b. [2points] Repeat the calculation for problem 1a, but now for the Earth, assuming Earth is a perfect sphere.

$$\frac{1}{T} = \frac{1}{2\pi} \sqrt{\frac{(6.67 * 10^{-8} \text{ cm}^3 \text{ kg}^{-1} \text{ s}^{-2})(6 * 10^{27} \text{ gm})}{(6400 \text{ km} * 10^5 \frac{\text{cm}}{\text{km}})^3}} = 2.0 * 10^{-4} \text{ s} = 0.708 \text{ hr}^{-1} \Rightarrow T = 1.41 \text{ hr}$$

Clearly, the earth is nowhere near this fast. However, it's worth noting that many asteroids *DO* rotate near their breakup limit.

2. Asteroid Composition [4 points] Calculate the average density (in gm cm^{-3}) of an asteroid with a mass of $1 * 10^{15} \text{ gm}$, and a radius of 0.5 km. Assume it is spherical. If the asteroid is made up entirely of iron (density of $\sim 7 \text{ gm cm}^{-3}$), what can you conclude about the asteroid's internal structure if the asteroid is perfectly spherical and uniform? If it is *not* spherical (though possibly uniform)?

$$\rho = \frac{\text{Mass}}{\frac{4}{3}\pi R^3} = \frac{1 * 10^{15} \text{ gm}}{\frac{4}{3}\pi(0.5 \text{ km} * \frac{10^5 \text{ cm}}{\text{km}})^3} = 1.9 \text{ gm cm}^{-3}$$

From the density calculation it is clear that the iron asteroid has a significant amount of empty space. However, from the density calculation alone, this is all we can say. If the asteroid were perfectly spherical and uniform, the low density would suggest microscopic voids. However, iron meteorites don't have microscopic voids. The empty space has two possible interpretations. One, the asteroid is just a large rubble pile where solid orblets are held together by gravity. There would be a lot of space between them. Also, if the asteroid is not spherical, then assuming it is for the density calculation would underestimate the density. Consider the asteroid Kleopatra.

3. Meteors

3a. [3 points] You find a "rock" on the Antarctic tundra. Write a minimum of four characteristics of this object that would suggest it's a meteorite.

Here are some, though not all possibilities:

1. *Simply finding it. Earth rocks are really rare on the surface of the ice.*
2. *The rock is undifferentiated. It may contain chondrules, spherical deposits that look like frozen droplets. Primitive stones are the most common types found in the Antarctic.*
3. *A fusion crust resulting from high-speed travel through the atmosphere*
4. *Isotopic ratios. Meteorites were formed in different parts of the solar system than the earth and they must have different elemental composition.*
5. *Take a reflectance spectrum of the meteorite and compare it to asteroid spectra. Often, meteorites come from the asteroid belt and they should share similar spectra.*

3b. [2 points] Is it possible, given your answers in 3a, this meteor originated from Mars? What evidence would be needed to be sure?

It is! Meteorites found in the Antarctic that are known to come from Mars had great influence on the vast amount of space missions that are and were at Mars. There are several discriminating factors between asteroid belt meteors and Martian meteors. The most important criterion is the presence of trapped gases that have the same composition as the Martian atmosphere.

4. **Comets** [5 points] Draw a diagram of a comet, including the coma, nucleus and ion and dust tails. On your diagram, show the path of the comet's orbit and the direction to the sun. Assume this comet is near the sun.

