The Average Density of Earth and Mars

How does the Earth's density change with depth ? Can we obtain an estimate of the average density of the Earth ? Let's approach this in a 2 step approach by calculating 1)The mass of the Earth, and then 2) Obtaining the Earth's volume. We should then be able to determine an average density.

Calculate the Mass of the Earth

We know the mass of the Earth from the strength of gravity at the Earth's surface. The strength of gravity is measured by the acceleration it causes to a falling body; a strong gravitational pull will accelerate a falling apple, more than a weak gravitational pull.

1. A theoretical approximation for gravitational acceleration, g, has been determined and is related to the Earth's mass, M, by this equation

$$g = \frac{GM}{r^2} \tag{1}$$

where G is a physical constant ($6.672 \times 10^{-11} m^3 kg^{-1} s^{-2}$) and r is the Earth's radius. Rearrange this equation to solve for the Earth's Mass. Show your work including change to each side of the equation and cancellations.

2. Now solve for the Mass of the Earth using your known values. Use the table below to obtain a radius measurement.

Table 1: Equatorial Radius of the Planets

Planet	equatorial radius (km)	equatorial gravity (m/s^{-2})
Mercury	2439	3.701
Venus	6052	8.870
Earth	6378	9.7803
Mars	3394	3.690
Jupiter	71398	23.1
Saturn	60330	8.96
Uranus	26200	8.69
Neptune	25225	11.0

Calculate the Volume of the Earth

3. If we have the mass of the Earth and can find its volume, the Earths' average density can be calculated. Estimate the volume of the Earth assuming the shape of a sphere. What is the general equation for obtaining the volume of a sphere ?

4. Using the information you already have, determine the volume of a spherical Earth.

Calculate the Density of the Earth

5. You now have the mass and volume of the Earth. How can you use these values to obtain the density of the Earth ? Give the general equation for obtaining this physical quantity.

6. Using the values you have already obtained for mass and volume, determine the average density of the Earth. Does your answer make physical sense ? Is it within the relm of possibility ?

7. Notice that it took 3 steps to obtain the desired value for the density of the Earth. Can you think of a way to combine these steps into one single calculation for density ? Are there any common variables in each equation which could be used in substitution ? If so, try this and show a new combined equation for density.

8. The equation you obtained above may be simplified for easier use. Try to simplify by grouping or cancelling terms. Please show all your work.

9. Now check your new equation by plugging in your known values and solving again for density. Please give your answer with appropriate significant figures.

10. Use the final equation you obtained for density to determine the average density of Mars. You can find values for radius and gravity in Table 1. Again, please give your answer with the correct number of significant digits.

In Figure 2 on the front page you will see a topography map of Mars as well as a magnetic field map. Researchers have suggested that in the lower central hemisphere of Mars linear alternating magnetic field lines have been observed (with an E-W orientation) which may be similar to magnetic anomalies observed on the Earth's seafloor. These anomalies, formed on the southern highlands, are some of the observations suggesting that Mars may have once had a magnetic field. Later when the northern lowlands formed (probably dense basaltic crust), no magnetic anomalies were created.

11. Let's assume that these magnetic anomalies were formed by some type of plate motion during formation. In this scenario, estimate the plate velocity during this time in the early Noachian history of Mars. The southern highlands were estimated to have formed in the first 50 My of Mars history. Here indicate the equation (from your lab on the Atlantic Ocean) which will help you solve this problem.

12. What is the age or time value you will use for plate motion of the southern highlands on Mars ?

13. Estimate the distance over which the magnetic anomalies are observed on Mars. To do this, determine the area covered by these anomalies. Use the lat/lon (which is better ?) of Mars for a distance scale. On Earth, the equatorial radius gives us the circumference to estimate the ration of degrees to surface distance ($1^\circ = 111km$) Using the radius of Mars, first calculate what this ratio will be for Mars.

14. Use the values you have above to calculate the plate velocity for the southern highlands on Mars during the formation of these magnetic lineations. Give your answer with the proper significant digits.

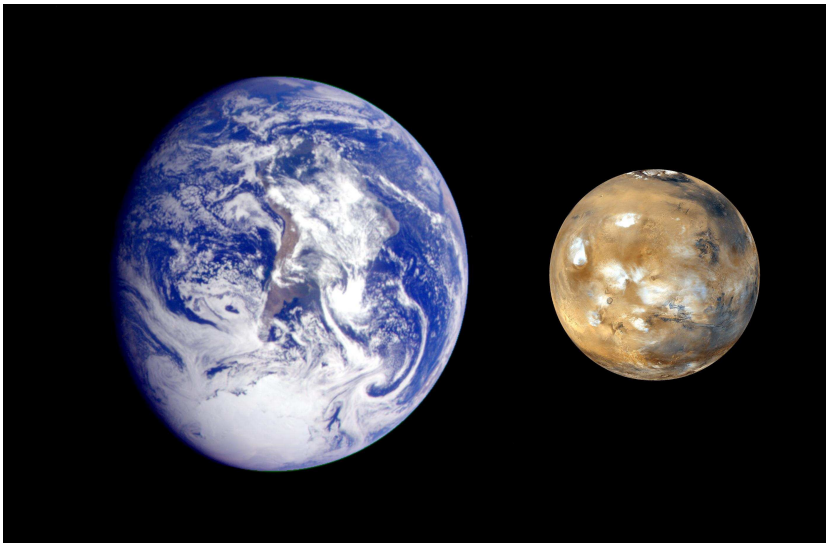
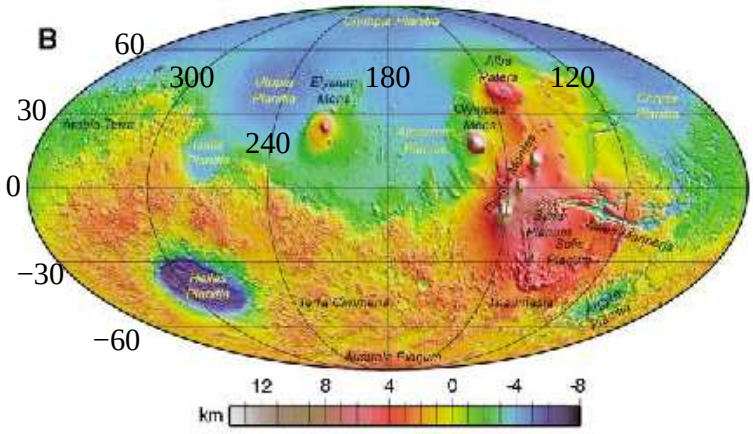


Figure 1: Lab #2. The Average density of Earth and Mars

Topography Map of Mars



Magnetic Field Observed on Mars