

NAME: Solutions

Section Number: _____

Homework 6: The Moon and Mercury

Due: in your section on **the week of March 3rd**. Be neat and concise, show your work, and remember units. An answer without the correct units is wrong.

Required reading: Lecture notes 13, 14 and 15, and chapters 2.3, 7.1, 8.4, 9.3, 10.3.

1. [2 Points] How do we know that craters on the Moon were formed by impacts, rather than volcanism?

Craters on the moon are generally lower than the surrounding topography and the larger craters are quite shallow compared to their rim height. Large craters also show central peaks or peak rings. Also, craters on the moon can be very big! It is difficult to come up with a process by which a volcanic crater could grow to be thousands of kilometers across. Volcanic craters tend to form as depressions on the tops of mountains and are smaller than most impact craters, with no central peaks. Finally, samples from the moon show evidence of violent impacts: the minerals are often melted together due to the heat of the blast, or cracked and damaged due to the shockwave.

2. [1 Point] What evidence of volcanism can easily be seen on the Moon and has recently been found on Mercury?

Large basins, such as the mare on the moon and the Caloris basin on Mercury are partially or completely filled with dark, solidified lava.

3. [2 Points] Why is the morphology (shape) of an impact crater different from the morphology of the crater formed when you throw a rock down in a sandbox?

The crater formed when you throw a rock in the sandbox is just due to the rock pushing the sand out of the way. An impact crater is formed when the enormous kinetic energy of the impactor is suddenly converted to heat energy. This catastrophic energy release results in the vaporization of the impactor and the surface, and causes a huge explosion. The explosion is what carves out the impact crater.

4. Moon Dirt

- a. [1 Point] What is the term for lunar soil?

Regolith – The layer of rocks on the surface of the moon. They have been crushed and pulverized by billions of years of impacts. (Note: Regolith is actually a generic term for a layer of crushed rock that lies on top of the bedrock. All the terrestrial planets and moons can have regolith on their surfaces.)

- b. [3 Points] How does a scoop of lunar soil differ from a scoop of soil from a flowerbed on Earth?

On Earth, the soil in a flowerbed contains a mixture of dead organic matter, micro-organisms, and weathered bits of rocks. It is generally quite water-rich. The lunar soil is a powder of tiny shards of pulverized crystals and glass that have formed through billions of years of impacts on the lunar surface. The minerals in lunar soil are completely dry and unweathered, except for “space-weathering” due to micrometeor impacts and the solar wind.

5. Formation of the Moon

- a. [3 Points] Briefly describe the leading theory for how the Moon formed. Give at least two lines of evidence that support this hypothesis.

The Moon probably formed when a large planetesimal roughly the size of Mars impacted the proto-earth. This impact completely melted both bodies, and blasted a ring of debris into orbit around the earth. This debris gradually accreted and formed the moon. Multiple lines of evidence support this hypothesis:

- *The moon has almost no volatiles. This makes sense, because any material that would be easy to vaporize would have been lost to space before the moon coalesced out of the debris from the impact.*
- *The moon has a small core. This makes sense, because a glancing impact would blast mostly mantle material into orbit, while the cores of the impactor and the proto-earth would merge to form the Earth’s final core.*
- *The moon has a similar oxygen isotope composition to the Earth, implying that it formed in the same part of the solar nebula. The Mars-sized impactor would have come from the same part of the nebula, so this makes sense.*
- *The mineralogy of the lunar surface implies that the Moon was once entirely molten. This is consistent with its formation from a cloud of debris from a giant impact.*

- b. [3 Points] Now, briefly describe two alternative theories for the Moon’s formation. For each, point out at least one flaw in the hypothesis.

Fission – The Moon broke off from a rapidly spinning proto-earth. Flaw: Does not conserve angular momentum, and matle compositions of the two bodies should be more similar.

Co-Accretion – The Moon is Earth’s “sister” world, which formed at the same time as the Earth. Flaw: Does not explain Moon’s low density and small core.

*Capture – The moon formed elsewhere, and was captured into orbit by Earth’s gravity.
Flaw: Does not explain similar isotope ratios.*

6. [3 Points] Mercury’s Core: How do we know that Mercury has a large molten core?

Based on the trajectories of spacecraft flying by Mercury, we can tell that it is very dense and therefore has a large core. Also, it has a magnetic field, which implies a molten core. Finally, its rotation rate varies in such a way that is best explained if part of the core is liquid.

7. [2 Points] Go to the following website and watch the animation of a day on Mercury:
http://btc.montana.edu/messenger/Interactives/ANIMATIONS/Day_On_Mercury/day_on_mercury_full.htm

- a. Why does the sun appear to slow down as it approaches midday? Why does it briefly reverse direction?

The sun appears to slow down as it approaches midday because Mercury is approaching its perihelion, and therefore has an increasing angular velocity around the sun. As the angular velocity approaches the planet’s rotation rate, the overall motion of the sun in the sky decreases. Right at perihelion, the planet is orbiting the sun faster than it is rotating, so the sun briefly appears to move “backwards” in the sky.

In equation form this is what is happening:

Rate of sun’s motion across the sky = Rotation Rate – Orbital Angular Velocity

So, you can see that as the angular velocity increases near perihelion (Kepler’s Second Law), the sun’s rate of motion will slow down.