

Solutions to Homework Problem Set 5

Chap 10 Q8: Key points:

Maria are dark and smooth lowlands with much less cratering than on highlands. They formed by impacts from large asteroids or meteoroids which broke the crust, so lava flow from below the surface flooded maria. Maria are found on the Earth-facing side and only one mare is seen on the far side. Maria are regions rich in iron (metal) carried by lava flows from the mantle.

In comparison, highlands are made of light-colored anorthosites. There are numerous craters on highlands. They are metal-poor regions.

Highlands are heavily cratered compared with maria, indicating that maria formed later than highlands so that craters produced in the first billion years were erased by lava flows, and the few craters present in maria were produced later. The relative ages of maria and highland terrains can be also confirmed by radioactive age-dating technique using rock samples taken back from various locations on the Moon.

Chap 10, Q 17: The Earth is much larger than the Moon and can retain more internal heat, which provides energy to fuel plate tectonics. Also, the plastic asthenosphere just below the Earth's thin crust allows convection to drive plate tectonics, and existence of ocean plates and continent plates makes possible the relative shift and cycling between ocean and continent plates. In contrast, the Moon has a smaller amount of internal heat and a rigid thick upper mantle below the crust, so plate tectonics can hardly be driven on the Moon.

Key: the mechanism of plate tectonics: driving force (or energy) and internal structure of the planet/satellite.

Chap 10, Q29: A few factors contribute to the significant temperature variations between day and night on the Moon. First, due to the synchronous rotation of the Moon, a day or a night on the Moon is as long as half a month. Second, the Moon's reflectivity is smaller than the Earth's, so the Moon absorbs more solar radiation flux (energy per unit area per second) than the Earth during the long day, thus the day-side hemisphere can become very hot compared with the night-side hemisphere. In contrast, the Earth's day or night lasts only 12 hrs and the Earth has a large albedo (reflectivity). Furthermore, the atmosphere and large body of water (oceans) on the Earth play important roles in moderating temperature variations. The Earth's atmosphere retains infrared radiation from the Earth at night so that the Earth does not cool down as quickly, while during the day, the atmosphere, especially with clouds, reflects a significant amount of sunlight. A large body of water has a very large heat capacity. It cools down or heats up more slowly than lands, so oceans on Earth can moderate temperature variations. In contrast, the Moon lacks both an atmosphere and liquid water.

Note: the underlying reason for all these is the Earth being massive and at the right distance

to the Sun.

Chap 3, Q8: (a) A person living on the Moon would see sunrise and sunset, because the moon rotates. Since the Moon's rotation period is a month, i.e., the interval from sunrise to next sunrise, is about a month. It is actually longer than a month, since during the month, the Earth-moon system also orbits the Sun by about 30 degrees, so the moon has to rotate a bit more to catch up. (b) The person would not see Earth rise or Earth set, because the Moon rotates at the same rate as it orbits around the Earth. As a result, at a location on the hemisphere of the Moon that is facing the Earth, the Earth is always at the same place in the sky (note that the visible face of the Earth changes during an Earth day because of the Earth's rotation), but at a location on the far side of the Moon, the Earth would not be in the sky at all. Strictly speaking, Earth would wobble back and forth a bit in the Moon sky, because the moon's orbit is elliptical, and the moon sometimes orbits a bit quicker than its rotation and sometimes a bit slower.

Note: to generalize, when a body A rotates at the same rate as it orbits around body B, a person on body A would see B staying at the same position in the sky, i.e, never rises or sets.

Key: the Moon's synchronous rotation.

Chap 5, Q28: From Figure 3-2 in the textbook, the answers are:

(a) There is 12 hrs apart between sunrise and moon rise, or 180 degree apart between the Sun's and Moon's positions, thus the phase is full moon.

(b) The moon rises 18 hrs later than the Sun (or 6 hrs earlier than the Sun), or 270 degree between the Sun's and Moon's positions, thus the lunar phase is third quarter moon.

(c) The Sun and the moon are at the same position in the sky, so the phase is new moon.

(d) The moon rises 6 hrs later than the Sun, so it is first quarter moon.

Key: Figure 3-2 in the textbook: the mechanism of the phase of the moon.

Chap 5, Q44: When the Earth is at aphelion, or the Sun is farther away from the Earth-Moon system than other times, the Moon casts a larger shadow (or umbra) on the Earth, and it thus takes longer time for a place within the umbra to move out of the umbra. Therefore, the duration of totality is maximum when the Earth is at aphelion, given that the Earth-Moon distance remains the same.

Key: solar total eclipse, umbra

A1: (a) The tidal force is, by nature, the difference in gravitational forces applied at the near end and far end of Earth. Suppose that the distance between the center of the moon and center of Earth is d_{EM} , and the radius of Earth is R_E , we may use Newton's law of universal gravitation to

calculate the gravitational forces at the two ends of Earth. At the near end, the gravitational force by the moon on 1 kilogram of mass (denoted by m) is given by

$$f_{near} = \frac{GM_M m}{(d_{EM} - R_E)^2}$$

and at the far end, the gravitational force is

$$f_{far} = \frac{GM_m m}{(d_{EM} + R_E)^2}$$

The tidal force, by definition, is the difference between f_{near} and f_{far} . Therefore,

$$f_{tidal} = f_{near} - f_{far} = \frac{GM_M m}{d_{EM}^2} [(1 - R_E/d_{EM})^{-2} - (1 + R_E/d_{EM})^{-2}]$$

Given that $R_E \ll d_{EM}$, we will apply the Taylor expansion to the expression in the parenthesis and keep only the zeroth order and first-order terms, such that $(1 - R_E/d_{EM})^{-2} \approx 1 + 2R_E/d_{EM}$ and $(1 + R_E/d_{EM})^{-2} \approx 1 - 2R_E/d_{EM}$. Therefore,

$$f_{tidal} \approx \frac{GM_M m}{d_{EM}^2} [(1 + 2R_E/d_{EM}) - (1 - 2R_E/d_{EM})] = \frac{4GM_M m R_E}{d_{EM}^3}$$

The result shows that the tidal force is inversely proportional to the cube of the distance, i.e., the farther away, the less effective, and is also proportional to Earth's size.

(b) In the same way, the tidal force by the Sun on Earth is given by

$$f_{tidal} \approx \frac{4GM_S m R_E}{d_{ES}^3}$$

where we change the moon's mass by the mass of the Sun, and the moon-Earth distance by Sun-Earth distance. To compare the tidal force by the moon to that by the Sun, we have

$$\frac{f_{tidal}^{moon}}{f_{tidal}^{sun}} = \frac{M_M d_{ES}^3}{M_S d_{EM}^3} = \frac{7.3 \times 10^{22} \text{kg} \times (1.5 \times 10^{11} \text{m})^3}{2.0 \times 10^{30} \text{kg} \times (3.8 \times 10^8 \text{m})^3} = 2.2$$

So, even though the Sun is massive, because of its far distance from Earth, the tidal force on Earth by the moon is nearly twice the tidal force by the Sun.