Astro 102/104 Our Solar System **Spring 2008**

NAME:_____*Solution*_____ Section Number:_____

Homework 5: The Earth

Due: in your section on **the week of Feb 25th**. Be neat and concise, show your work, and remember units. An answer without the correct units is wrong.

Suggested reading: Lecture notes 11 and 12, and corresponding chapters from the book.

1 Earth's One Large Moon

a. [1 point] Using Tables E.1 and E.3 in your text, compute the ratio of the Moon's mass to that of the Earth, written as a decimal number (e.g., 0.05).

(Moon's mass) / (Earth's mass) = (7.349x10^{22} kg) / (5.97x10^{24} kg) = ***0.0123***

b. [3 points] Compute the same ratio for the solar system's other planets (the ones with moons), plus Pluto. Use the most massive moon for each planet. Show your work, but also enter the final values in the table.

Planet Name	**Moon Name**	**Mass Ratio**
Mars	*Phobos*	*2.0x10^{-8}*
Jupiter	*Ganymede*	*7.80x10^{-5}*
Saturn	*Titan*	*2.37x10^{-4}*
Uranus	*Titania*	*4.06x10^{-5}*
Neptune	*Triton*	*2.08x10^{-4}*
Pluto	*Charon*	*0.119*

c. [1 point] Which of these bodies have mass ratios at least as large as that computed for the Earth's Moon in part a?

Only ***Pluto****, with its large moon Charon.*

2 [1 point] How do we know what is inside the Earth—i.e., that Earth has a solid/liquid core, mantle, etc?

*In a word, the answer is **seismology**. Seismic waves, generated by earthquakes or by artificial means, travel through the Earth at speeds that depend on the densities of materials that they travel through. Changes in density bend the paths of these waves. By timing the arrival of seismic waves at locations spread across the Earth's surface, it is found that the Earth has a dense core overlain by a mantle that is less dense. In addition, P waves (primary, pressure, or pushing) can travel through a liquid while S waves (secondary, shear, or side-to-side) cannot. By observing the pattern of P and S waves that make it through the core, it is found that the outer portion of the core is liquid, while the inner core is solid. The measured densities and states (liquid vs. solid) of materials in the Earth's interior can be used to infer compositions, temperatures, and pressures.*

3 [2 points] Name the three major types of rocks in Earth's crust, and an environment in which each of these rock types would form.

***Sedimentary** rocks form when eroded fragments of other rocks are deposited, buried and compacted, and/or cemented together. As an example, shales form when tiny clay particles settle out of an ocean or sea and accumulate on the bottom. **Igneous** rocks form when part of the Earth's mantle or crust is melted, and subsequently cools and crystallizes. Basalt, formed as lava hardens on the slopes of the Kilauea volcano in Hawaii, is one fairly common igneous rock. **Metamorphic** rocks can form when rocks from the surface are transported to great depths, e.g. in a subduction zone, where the high temperatures and pressures in the subsurface cause changes to the mineralogy.*

4 [2 points] List at least four independent pieces of evidence for plate tectonics on the Earth. Describe how each observation is explained by plate tectonics.

Magnetic stripes appear on the seafloor because new crust is continually forming and spreading at mid-ocean ridges, which are in fact boundaries between plates. Newly formed crustal rocks align with the Earth's magnetic field, which reverses periodically, causing the stripes of alternating polarity. The young age of the seafloor, measured using radioisotope dating and confirmed by the paucity of impact craters on the ocean floor relative to the continents, requires that the Earth's crust be continually changing, consistent with the theory of plate tectonics. Similar fossils and rock types are found in eastern South America and western Africa; this is explained by the fact that these two continents used to be adjacent, and have spread apart due to plate motion. The matching coastlines of eastern South America and western Africa provide even more support for this claim.

5 Greenhouse Effect

a. [1 point] The surface of the Earth absorbs mostly visible light, but emits infrared light that has a much longer wavelength. Why?

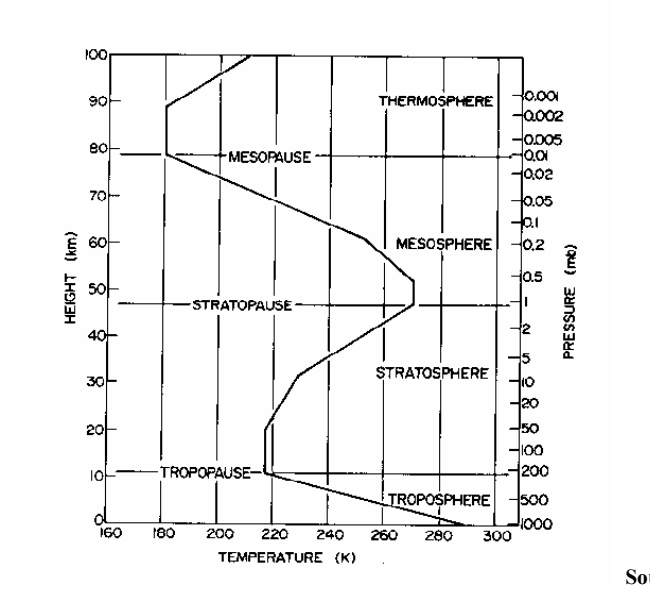
The light absorbed by the Earth comes from the Sun, which radiates approximately as a blackbody of temperature T~5800 K. The Earth also radiates approximately as a blackbody, but has a much lower surface temperature of T~290 K. The Earth's lower temperature explains its longer-wavelength radiation peak, in accordance with Wien's law.

b. [1 point] Does the greenhouse effect change the rate at which Earth radiates energy to space? Explain.

No; the greenhouse effect merely raises the temperature of the lower atmosphere. No matter how strong the effect, the Earth always radiates exactly as much energy as it receives from the Sun. If this balance did not exist, then the planet would steadily and continuously heat up even if the abundance of greenhouse gases remained constant, which has not happened (otherwise, Venus would have melted by now).

6 Structure of the Atmosphere

a. [2 points] Graph the Earth's atmospheric temperature profile, with temperature on the horizontal axis and altitude on the vertical axis. Label the layers of the atmosphere.



Source: http://www.marine.rutgers.edu/mrs/education/class/yuri/t_sounding.html

b. [2 points] There are three levels at which Earth's atmosphere approaches or exceeds 0 ºC. What is the source of the warmth at each of these levels?

The lower troposphere is warm because its greenhouse gases absorb the infrared radiation from the Earth's surface. The upper stratosphere is warm because absorption of UV sunlight by ozone molecules is strongest at that altitude. The upper thermosphere is warm due to absorption of x-rays from the Sun. All gases absorb these rays, but they do not penetrate deeper into the atmosphere than the thermosphere.

c. [1 point] Do Venus and Mars have the same three warm levels in their atmospheres? Explain.

Venus and Mars also have relatively warm lower troposphere due to absorption of infrared radiation from the surface, and warm upper thermospheres due to absorption of x-rays. But neither Venus nor Mars has an oxygen-rich atmosphere, and thus neither has enough ozone to absorb ultraviolet light and create a warm stratosphere.

7 [2 points] Describe four *natural* factors that can lead to long-term climate changes.

Solar brightening *throughout the Sun's lifetime gradually increases the radiation reaching all planets in the solar system.* ***Obliquity (spin axis tilt) changes*** *occur on Earth and on other planets, and change the relative amounts of radiation reaching the poles vs. the equatorial regions.* ***Albedo changes*** *(e.g., due to changing cloud abundances or surface ice cover) can increase or decrease the fraction of sunlight reflected (rather than absorbed) by a planet. Finally,* ***greenhouse gas abundances*** *can change by many natural means, e.g. volcanic eruptions.*

8 [1 point] Where did Earth's atmosphere come from?

Volcanic outgassing *has probably been the primary source of Earth's atmosphere. Additional contributions are from impact delivery of ices and hydrated minerals, and evaporation or sublimation of surface liquids and ices. The Earth (and other terrestrial planets) likely did NOT retain any "primordial atmosphere" from the time of planetary accretion; such an atmosphere would have been stripped away by early large impacts and the solar wind.*