PTYS/ASTR 206 – Section 3 – Homework 4 – Assigned 3/12/09

NAME:____

(PRINT CLEARLY)

- Homework is due <u>in class</u> on Thursday March 26th.
- Late homeworks can be turned in class on Tuesday April 2nd for 50% credit.
- Homeworks turned in later than this receive 0%.
- Students are encouraged to discuss approaches to solving homework problems with each other; however, all work submitted must be the student's own. **<u>Do not turn in identical homeworks!</u>** See the syllabus for more information.

Hint: Each of these questions should be quick to answer. If you find yourself engaged in a long chain of complicated reasoning or more than a few lines of math then something is probably wrong! Make sure to start this early and talk to the TA or myself with any questions.

Question 1: Density of the planets

Use the information in this table to figure out the volume and density of these planetary objects.

Planet	Mass (kg)	Radius (km)	Volume	Density
Mercury	3.3×10^{23}	2438	$6.1 \times 10^{19}\ m^3$	$5410\ kg\ m^{-3}$
Venus	4.9×10^{24}	6052	$9.3 \times 10^{20}\ m^3$	$5269\ kg\ m^{-3}$
Earth	6.0×10^{24}	6371	$1.1 \times 10^{21}\ m^3$	$5455\ kg\ m^{-3}$
Mars	6.4×10^{23}	3396	$1.6 \times 10^{20}\ m^3$	$4000\ kg\ m^{-3}$

$$\text{Volume} = \frac{4}{3}\pi(\text{Radius})^3$$

↑ Convert to meters first!

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

PTYS/ASTR 206 – Section 3 – Homework 4 – Assigned 3/12/09

The density of regular surface rock is about 2700 to 3000 kg m^{-3}. Are the planetary values you figured out above higher or lower than regular surface rocks? What does that tell you about the interiors of these objects?

They are all higher.
This indicates that the interior material is denser than the surface rock. In the case of these planets, it's because they all have iron cores.

If we used the above method on asteroids we would find that the density of asteroids is much lower than the density of meteorites. Why is this? (you need to think a bit beyond the lecture material for this one).

By analogy with the question above this would indicate that the interior of the asteriod is less dense than surface rock.
In this case, these asteroids are not solid and have empty space inside them which lowers their bulk density. Much like a pile of loose rock on the Earth has empty spaces between the individual rocks.

Question 2: Plate Tectonics

North America drifts westward and Europe drifts eastwards, each by about 1cm per year. If the Atlantic Ocean is about 3000km wide today then how long ago has it been since these two continents split apart?

Oceans widen by 2 cm per year.

3000 km is 3000,000 m or 300,000,000 cm.

$$\frac{300,000,000 \text{ cm}}{2 \text{ cm/year}} = 150,000,000 \text{ years}$$

150 million years

PTYS/ASTR 206 – Section 3 – Homework 4 – Assigned 3/12/09

The dinosaurs were killed off by a giant impact in Mexico about 65 million years ago. Did the Atlantic Ocean exist at that time? If so, how wide was it?

Yes, it existed for 85 million years at that point.

85 million years x 2 cm/year = 170 million cm

170 million cm = 1.7 million meters = 1700 km

How is continental crust made? A few years ago a continental rock (Andesite) was found to be common on Mars. This has since been disputed, but why would this be so significant if it were true?

Continental rock is made by remelting oceanic crust. On Earth this is done with plate tectonics by taking an oceanic plate and subducting it back into the mantle (where it melts and gets erupted onto continents through volcanoes).

Continental rock on Mars would indicate the operation of plate tectonics, something we think only works on the Earth.

Question 3: Ancient Mars and Earth

The past climate of Mars was much more favorable for liquid water. Why did this favorable climate disappear whereas on the Earth it persisted?

Greenhouse gases (mostly CO_2) were drawn out of the atmosphere on both planets by disolving in water and reacting with rocks.

On Earth this CO_2 was replaced by volcanoes but volcanic activity on Mars mostly died off early. Mars lost it's greenhouse effect and so cooled off.

PTYS/ASTR 206 – Section 3 – Homework 4 – Assigned 3/12/09

Ancient rocks on Mars show that the planet once had a magnetic field. Why did this field disappear whereas on the Earth it persisted?

The field disappeared when the liquid iron core froze through. This did not happen yet for the Earth as it's a larger planet. Larger planets have a higher volume per unit surface area ratio. Heat produced is proportional to volume and heat lost to surface area so larger planets cool off more slowly.

Currently the heat flow from the interior of Mars is 0.03 Wm^{-2} and from the Earth is 0.08 Wm^{-2}. Use values in the table for question 1 to figure out the surface area (area of a sphere is $12.6*R^2$, where R is the radius) of each planet and use that to figure out how much energy each planet is producing per second.

How much energy per second is being produced per kilogram for each planet (the masses of these planets are also in that table)? Are these numbers very different? Why do you suppose that is?

Mars

surface area $= 12.6 \times R^2 = 1.5 \times 10^{14}\ m^2$

Total heat per second $= 0.03\ Wm^{-2} \times \text{Area}$

$= \boxed{4.4 \times 10^{12}\ \text{Watts}}$

Heat per kilogram per second $= \frac{4.4 \times 10^{12}\ W}{\text{mass}} = \boxed{6.9 \times 10^{-12}\ W\ kg^{-1}}$

Earth

Surface area $= 5.1 \times 10^{14}\ m^2$

Total heat $= 0.08\ Wm^{-2} \times \text{Area} = \boxed{4.1 \times 10^{13}\ \text{Watts}}$

Heat per second per kilogram $= \frac{4.1 \times 10^{13}}{\text{mass}} = \boxed{6.8 \times 10^{-12}\ W\ kg^{-1}}$

These numbers are very similar so 1 kg of the Earth and 1 kg of Mars produce the same amount of energy from radioactive decay. Not surprising since they're both rocky planets made from the same stuff.

PTYS/ASTR 206 – Section 3 – Homework 4 – Assigned 3/12/09

Question 4: Moon and Asteroids

Mars has two Moons Phobos and Deimos, which are thought to be captured asteroids. They orbit the planet in 7.7 and 30.2 hours respectively. What does their motion look like as seen from the martian surface? Think about the spin rate of Mars here.

Mars spins in about 24½ hours which causes the fixed stars to rise in the east and set in the west.

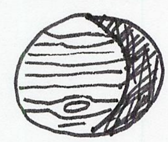
Deimos moves slower than this and so appears to follow the stars although not as quickly.

phobos moves faster than this and so appears to move in the opposite direction. e.g. rises in the west

How would the phase of Jupiter vary as seen from a Trojan asteroid over the course of one Jupiter year?

see Figure on extra sheet

It wouldn't, the relative position of the sun, Jupiter and the Trojan is fixed. The asteroid would see a Jupiter that looks a little more than half full. →



Asteroids in a 3:1 resonance with Jupiter orbit the sun three times everytime Jupiter orbits once. Use the formula for Kepler's third law in earlier lectures/homeworks to figure out what the semimajor axis of these asteroids is (Jupiter's semi-major axis is 5.2 AU).

$(\text{Period})^2 = (\text{semi-major axis})^3$ ← Keplers 3rd Law; P in years, a in AU

Asteroid → $P_A^2 = a_A^3$

Jupiter → $P_J^2 = a_J^3$

Divide these two formulas $\left(\frac{P_A}{P_J}\right)^2 = \left(\frac{a_A}{a_J}\right)^3$

so: $a_A = a_J \left(\frac{P_A}{P_J}\right)^{2/3}$

$\frac{P_A}{P_J} = \frac{1}{3}$ & $a_J = 5.2$ AU $\quad a_A = 5.2 \left(\frac{1}{3}\right)^{2/3}$ AU $=$ **2.5 AU**

PTYS/ASTR 206 – Section 3 – Homework 4 – Assigned 3/12/09

Question 5: Earth

What three things set the Earth apart from the other planets (two of these things are linked)?

An Oxygen rich atmosphere ← } Linked as Life produces this oxygen
Life ←

Plate Tectonics

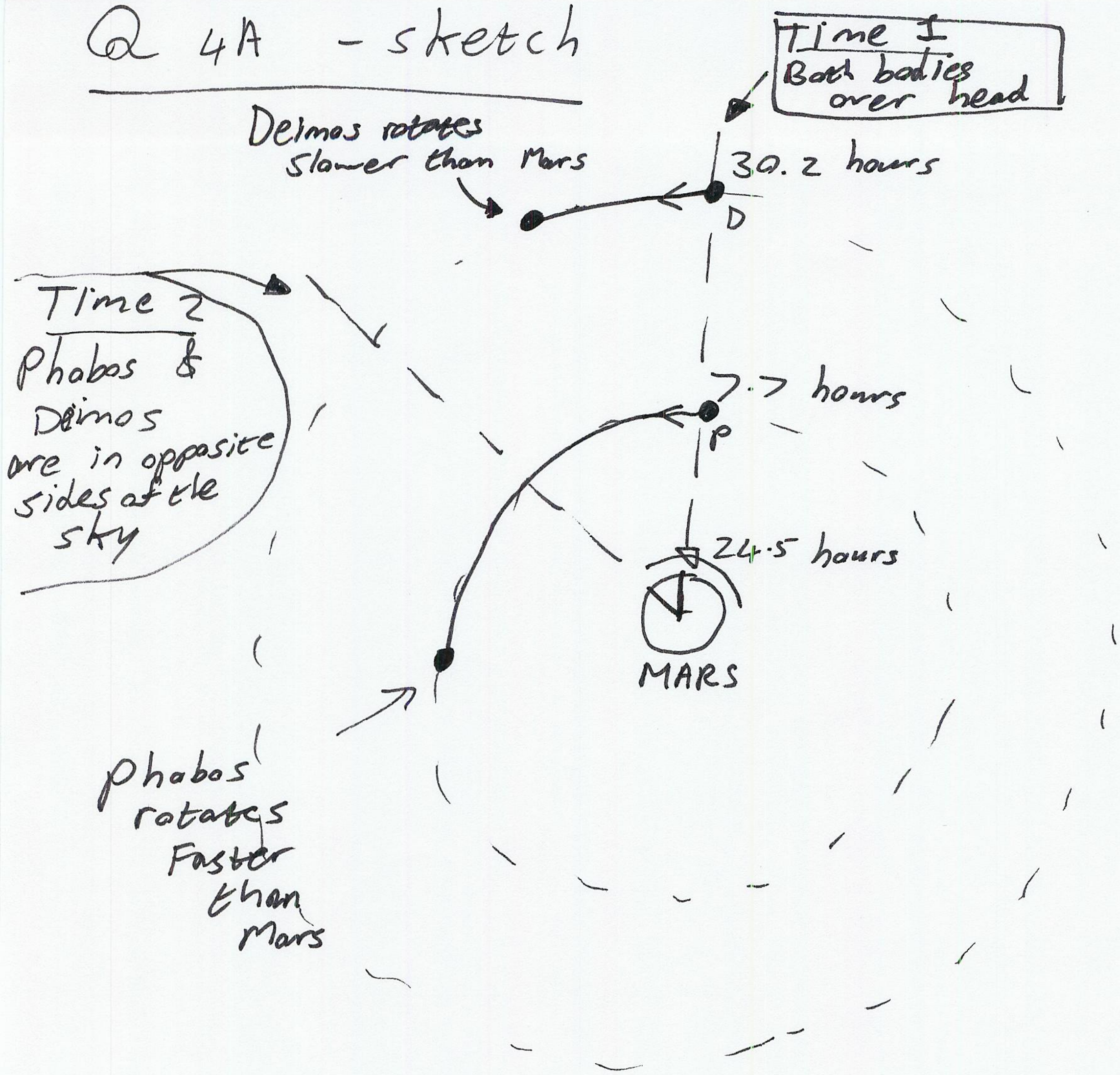
Earth probably had many smaller tectonic plates in its early history. Why do we think this is? Extrapolate this forward a few billion years. What will happen to plate tectonics as the Earth ages?

Plate tectonics is an important ~~w~~ way for Earth to lose heat – by pushing cold surface plates into the mantle.
Early in Earth's history, the planet had more heat it need to loose. Smaller (and more numerous) plates can accomplish this by pushing cold plates into the hot mantle in more locations.

Occasionally Earth enters a climatic state called snowball-Earth. Here the Earth gets a snow cover that is bright and reflects away most of the sunlight. As less sunlight is absorbed the Earth gets even colder and the snow cover expands to cover more area etc... pretty soon the whole Earth is covered with ice and is very cold. How did Earth escape from these periods? This isn't in the lecture notes so you need to think a bit to get the answer, comparisons to Mars would be useful.

If all the water is frozen then nothing removes CO_2 from the atmosphere. Volcanoes never stop working and keep adding CO_2 to the atmosphere. CO_2 levels build up and the extra greenhouse effect breaks us out of the snowball state.

Q 4A - sketch



Top down view From above Mars' north pole (+)

D = Deimos
P = phobos

Everything spins/rotates anticlockwise.

North is towards the center.

So: phobos is in the East } AT time 2
Deimos is in the West }

Phobos moved west to east

Deimos moved east to west.