SOLUTIONS

PTYS/ASTR 206 – Section 3 – Homework 3 – Assigned 2/26/09

NAME:____________________________________

(PRINT CLEARLY)

- Homework is due in class on Thursday March 5th.
- Late homeworks can be turned in class on Tuesday March 10th 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. **Do not turn in identical homeworks!** 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: Planetary interiors

Give two reasons why we know the core of the Earth is at least partly liquid?

1) Earthquakes: Explain 2 kinds of waves (P, S)
S waves can't travel through liquids.
Liquid outer core leaves a shadow zone with no S-waves

2) Earth's internally generated magnetic field: only possible if Earth has a liquid core

When rocks rise up through the Earth's mantle why do they partly melt?

As rocks rise up through Earth's mantle, temperature varies with change in pressure.

In the deep mantle, temperature $<$ melting point
$\Rightarrow$ deep mantle is solid

Higher up in the mantle temperature $>$ melting point,
$\Rightarrow$ Rocks start melting

(A simple sketch of temperature variation in Earth's interior would be helpful, though not required – Page 12 of Interiors Lecture)

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Volcanoes with very viscous lavas have very explosive eruptions. Give three reasons why some lavas are more viscous than others.

1) Silica content (SiO_2) / Composition of Lava;
High silica content ⇒ high viscosity
2) Temperature: High eruption temperature
⇒ Low viscosity
3) Adding water lowers viscosity

You might already have heard about the Mount St. Helens eruption during 1980 in Washington State. Do a little web research on this eruption, what kind of volcano is this? The mountain itself was badly damaged in the eruption – what will happen to this volcano in the future?

Stratovolcano – explosive, destructive eruption
- Recent dome building episode (regaining height)
- Ongoing steam eruptions
- Will it erupt again? Has it become dormant?

Question 2: Atmospheres of terrestrial planets

The surface pressure of the martian atmosphere is about 0.006 times that of the Earth and the scale height of Earth's atmosphere is about 8km. Is the top of Mount Everest at lower or higher pressure than the surface of Mars (elevation of Mount Everest is 8.8km)?

8 km = 1 Scale height
⇒ 8.8 km = 1.1 scale heights

Pressure at top of Mt. Everest $= P_0 \left(\frac{1}{e}\right)^{1.1} \sim 33\%$ of P_0
$= 0.33 P_0$

This is higher pressure than at the surface of Mars $(0.006 P_0)$.

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Both Earth and Titan have mostly nitrogen atmospheres at roughly the same pressure. Temperature on Titan is 90K and on the Earth 300K. How dense is Titan's atmosphere compared to the Earth?

$$\text{Density} \propto \frac{1}{\text{Temperature}}$$

Higher temperatures make atmosphere less compact (less dense)

$$\frac{(\text{Density})_{\text{Titan}}}{(\text{Density})_{\text{Earth}}} = \frac{(\text{Temperature})_{\text{Earth}}}{(\text{Temperature})_{\text{Titan}}} = \frac{300}{90} \sim 3.3$$

How do we know there is ice in Mercury's polar regions? Why is it stable there despite Mercury being such a hot planet?

Evidence for ice in Mercury's polar regions

Radar reflections show craters are filled with unusual material (probably water ice)

Why is ice stable? - Polar craters are permanently shadowed;
- Mercury has low obliquity
- Solar elevations in polar regions are always low

Question 3: Atmospheric Circulation

What latitudes contain most of the deserts on the Earth? What causes this?

Tropics (30°N, 30°S) contain most of the deserts.

Air gets heated at the equator. Hot air rises and cools off. Clouds form and lots of rain results at equator. The dry air is pushed aside from equator. It moves to the tropics, descends to the surface and heats up - dry air creates deserts. (Hadley cell circulation) (A sketch of circulation cells on Earth would be useful).

(*) Venus is hotter ∴ it's closer to the Sun. All the water on Venus evaporated away long time back. This increased the surface temperature (∵ H_2O is a greenhouse gas), vaporised rocks to form CO_2. (*) There was no plate tectonics on Venus to put CO_2 back in rocks. Kept getting hotter! Evaporated all H_2O & CO_2 eventually.

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Which way do winds at Earth's equator blow? (Sketch a picture). Where does this ~~air~~ come from and why do these winds blow in this direction?

- Explain Coriolis force → Caused due to rotation of the Earth.
- In N hemisphere, winds are deflected to the right. - In S hemisphere, winds are deflected to the left.
- Winds blow towards west.
- Sketch of zonal winds is required here.

How does the greenhouse effect work? Why does adding more CO_2 to the atmosphere change the climate? Why did Venus's greenhouse effect run away while the Earth's is kept in check?

- Sunlight comes in (mainly at visible wavelengths). Greenhouse gases are transparent to visible light, allow it to pass through. Ground gets heated up and emits infra-red radiation. Greenhouse gases are opaque to IR, which gets blocked. This increases the temperature, resulting in the greenhouse effect.
- CO_2 is a greenhouse gas. Adding more CO_2 boosts the greenhouse effect, increases the surface temperature.
- (*) Top.

Question 4: The Moon

Most people now believe that the Moon formed in a giant collision between the Earth and a passing Mars-sized planet. Give two pieces of evidence to support this.

- Moon is depleted in iron and volatile substances
- Oxygen isotope ratios similar to the Earth

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An old formation theory involved the Moon and Earth splitting apart from a rapidly spinning parent body. Why doesn't this work?

Moon doesn't orbit in Earth's equatorial plane.

What are the dark low-land plains on the Moon composed of? Why do they have much fewer impact craters than the bright lunar highlands? Why are these dark plains concentrated on the side of the Moon that faces the Earth?

- Basalt (volcanic composition)
- Volcanic flows were emplaced on top of craters ⇒ volcanic flows are younger than the impact craters. The younger dark low-land plains on the Moon thus have fewer craters.
- The dark plains are concentrated on the side of the Moon that faces the Earth ∵ of thinner crust on the near side.

Question 5: Venus

Most volcanoes on Venus produce lava that is not at all viscous. Suggest a reason why the viscosity of the Venusian lavas is so low.

High surface temperature (750 K) leads to low viscosity.

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Venus is 0.72 AU from the Sun. Assume Venus had no atmosphere and that its bare surface reflected 50% of the sunlight that hit it. How much solar power would it absorb on each square meter? If the temperature was stable then this absorption would be balanced by emitted energy. What would be the temperature in this case?

[Hint: you solved a problem almost just like this in the last homework]

Incident solar power $= \frac{1367}{R^2} = \frac{1367}{0.72^2}$

$\sim 2637 \ W/m^2$

50% of the incident energy is reflected back

$\Rightarrow$ 50% is absorbed $= 0.5 \times 2637 \simeq 1318 \ W/m^2$

If absorption is balanced by emitted energy

$\Rightarrow 1318 = \sigma T^4 = (5.67 \times 10^{-8}) T^4$

$\Rightarrow T^4 = 1318 / (5.67 \times 10^{-8}) \Rightarrow T \simeq 390.46 \ K$

What is the actual surface temperature on Venus? How big of an effect is the atmosphere having?

Actual surface temperature on Venus $\simeq 750$ K

$\Rightarrow$ Atmosphere has a huge effect

- Surface is warmed by greenhouse effect.
- Greenhouse gases stop thermal radiation from escaping to space.
- Venus has 86 bars of CO_2 $\Rightarrow$ Temperature is boosted by about 400°C.