

Homework 2:

assigned: Thus, Oct 9

due: Thur, Oct 16

Required Readings:

Name: _____

Part I.

1. *Temperature Scales:* Fill in the following table, making the necessary conversions:
[8pts]

°C (Celsius)	K (Kelvin)	°F (Fahrenheit)
		32
		212
15		
	0	
		100

2. (a) Is the Earth currently in an ice-age or an interglacial period? [2 pt] (b) How long has the Earth been in this state? [2 pt]

3. *Isotopes:* (a) Give the primary isotopes of carbon and oxygen, and state which ones are stable and unstable (radioactive) [3 pts] (b) What climate parameter is derived from the proportion of "heavy oxygen" in ocean sediments? [2 pt] (c) What climate parameter is derived from the proportion of "heavy oxygen" in ice-cores? [2 pt] (d) Explain your answer to b. That is, explain why "heavy oxygen" in ocean sediments serves as a proxy for the climate parameter you stated in answer to b. [4 pts]

4. *Earth history:* Give the approximate dates associated with the following. Example: Formation of Earth. Answer: 4.6 billion yr. BP (years before present). (a) Origin of life. (b) Atmospheric oxygen reaches levels similar to today. (c) Late Proterozoic glaciations that encased the entire earth just prior to the Cambrian explosion of life. (d) Beginning of the abundant fossil record of multicellular life. (e) Extinction of the dinosaurs by an asteroid impact. (f) Beginning of Pleistocene Glaciations - that is, the modern epoch of alternating glacial/interglacial conditions. (g) End of the most recent glaciation. [8 pts]

5. *Ice-ages:* For the past 3 million years or so, the Earth has gone in and out of ice-ages. It is thought that changes the Earth's orbital parameters are the trigger for these oscillations and that this initial trigger is strongly amplified by positive feedbacks in the climate system. (a) What is the immediate "trigger" of an ice age? That is, what aspect of solar energy input to the Earth is thought to cause ice-ages to begin or end? Explain your answer. [2 pts] (b) Describe how the ice-albedo feedback would logically be connected to this trigger. Specifically, describe how an ice-age might begin, based on the orbital trigger and the ice-albedo feedback. [4 pts] (c) Why is it thought that changes in atmospheric CO₂ are also part of a positive feedback helping to drive the

ice-age cycles? (You needn't try to explain how this feedback works - even climate scientists are not sure.) [4 pts] (d) Referring to Houghton Figure 4.6 (p.72), what is the only prolonged period of relative climate stability in this 100,000 year ice-core record from Greenland? [2 pts]

Part II-Model B

The equation for energy balance at the surface, $E_{IN} = E_{OUT}$, can be rewritten as:

$$\boxed{S_0(1-\alpha)\pi R_e^2 + \epsilon\sigma T_a^4 4\pi R_e^2 = \sigma T_s^4 4\pi R_e^2} \quad (1)$$

A B C

where S_0 is the solar constant (in units of W/m^2), α is Earth's albedo(no units), σ is the Stefan-Boltzmann constant ($5.67 \times 10^{-8} W/m^2K^4$), T_a is the effective radiating temperature of the atmosphere (in Kelvin), T_s is the effective radiating temperature of the surface (in Kelvin), and R_e is the Earth's radius.

- (a) Explain why the term A of (1) is multiplied by πR_e^2 , as opposed to some other multiple of πR_e^2 , like $4\pi R_e^2$ or $2\pi R_e^2$. [2 pts]
- (b) Why is the term B multiplied by the emissivity, whereas term C is not? [2 pts]

The energy balance for the atmosphere is

$$\boxed{\epsilon\sigma T_s^4 4\pi R_e^2 = \epsilon\sigma T_a^4 8\pi R_e^2} \quad (2)$$

A B

- (c) Why are both terms multiplied by the emissivity? [2 pts]
- (d) Why is term B multiplied by $8\pi R_e^2$? [2 pts]

Combining (1) and (2) together gives

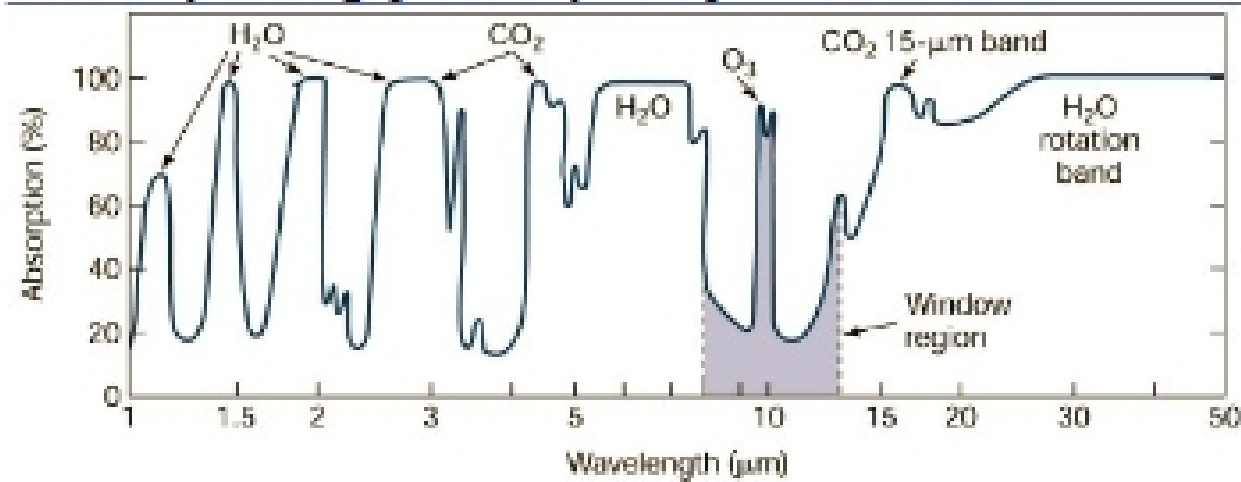
$$\boxed{T_s = \sqrt[4]{\frac{S_0(1-\alpha)}{4\sigma(1-\epsilon/2)}}} \quad (3)$$

- (e) For modern day values of T_s (288K), S_0 (1370 W/m^2), and α (0.30), what does ϵ need to be for radiative balance? [2 pts]
- (f) Three billion years ago, the sun's output was 78% of its modern day value. If the atmosphere had the same greenhouse gas distribution as today, what would be the surface temperature? (hint: used model B). State your assumptions. [2 pts]
- (g) Concerning the discussion in problem (f), the earth's surface temperature 3 billion years ago was much warmer than today. Revisit your answer to part f above. What must be true? Explain [3 pts]

Part III

9. (a) Explain why less solar energy is absorbed at high (i.e. polar latitudes) latitudes than at low (i.e. tropical) latitudes.
 (b) Explain why more longwave (infrared) energy is emitted at low latitudes than at high latitudes.

10. Given the following spectrum of atmospheric radiation:



- (a) What percentage of radiation in the 6-7 μm wavelength is absorbed by the atmosphere?
 (b) If you were to add a greenhouse gas to the atmosphere, and you wanted it to absorb as much radiation as possible, would you add a gas that absorbed at wavelengths between 8 and 9 μm or between 16 and 17 μm ? Why?