**Earth's Energy Budget- Inflow and Outflow**

According to the CSET test guide, there will be a total of 50 mutliple choice questions and three constructed response questions for CSET 122.

**a. Compare the amount of incoming solar energy, the Earth’s internal energy, the energy used by society, and the energy reflected back to space**

A black body (black rock), and you heat it, it starts emitting energy. Like, as a hot nail, it glows in the red because that that temperature, it is in the red portion of the spectrum. And continue heating it and it turns orange, then red, onto white. As temperature increase, the peak of energy radiation peaks towards shorter and shorter wavelengths. So, at temp of 6000 degrees K, the max happens to be in the visible spectrum. Organisms evolved eyesight to take advantage of the maximum amount of energy and that's why are eyesight is in tuned to the visible portion of the spectrum. Now the sun provides tons of very short wavelengths and oodles of high wavelengths of energy. The ones we see is just in the small portion of the visible wavelength spectrum. THe earth is also black body but at a much lower temperature. At 6000K (sun) and earth is 300K. So, earth peak of radiation is about 10 micrums, the thermal inferred portion of the spectrum. THe sun is beaming to us peaking at the visible and we are radiating back to the universe but at the 10 um. The earth is like a filter, allows passage of some wavelengths but not others.

Black body radiation:

-All bodies radiate energy

-the dominant wavelengths of radiated energy are a function of the temperature of the radiating body.

-So, the hot glowing body will have the tensity to emit most of it's energy in the visible portion of the spectrum, whereas a cool body, like the earth, will emit in the thermal portion of the spectrum.

Part of the solar radiation is backscattered by molecules. Backscatter light is not a directed beam, it's going everywhere. The best backscattering happens in the blue portion of the spectrum. So, sky is not blue, but because the light that is being diffuse is in the blue portion of the spectrum. Some of the solar radiation makes it through and is absorbed by water vapor, dust, ozone, h2S, so4, etc. With enough energy to that molecule and at just the right wavelength, the hydrogens will start to separate and vibrate and will consume part of the energy. Same with o3 molecule. They start vibrating. So, water is the big player, it absorbs fair amount of energy. Some energy is reflected by clouds. Clouds have a high reflective, albedo. The ocean has a very low albedo, it absorbs quite a bit energy. So, some hits the surface of the ground. The high albedo of the clouds look white because they are reflecting all of the visible portion of the spectrum. The deserts have relatively high albedos. The green portion has been lost (the red has been absorbed by the plants but reflects the green). Poles have high albedos, reflects back quite a bit. Then you have the dark water. Water is not a good reflector. Of everything that is on earth, the ocean has the lowest albedo. They are the ones that absorbs the most.

**Albedo**= Reflected energy/incident energy

So, Albedo ocean= 0.3 to 0.5, third to half of what is incident is reflected

Albedo land = .6 to .8 (80% is reflected)

Albedo snow/clouds= .7 to .9 (90% is reflected)

Absorbent bands of different compounds with respect to different wavelengths. Remember that the sun happens to emit most of its energy in the visible potion of the spectrum. It turns out that many of the compounds like water carbon dioxide has a transmission window. So the energy that is produced at that wavelengths does not resonate. So, accordingly, energy can pass through the atmosphere at that particular wavelength. So, a fair amount strikes here. Good for us. Water lets the visible potion radiate through. On the other hand, the earth emits around the 10 micrum. So, at 6 spectrum, it would be completely absorbed there. Co2 doesn't do much here. Oxygen, happens to have a peak right around 9 micrums, so oxygen absorbs any energy that comes through them. So, as the energy goes out, it finds all these filters (water co2 o2, takes a chunk. The molecules absorbs and radiates it back around the 10mincrum spectrum). Note that the water window is a relatively narrow one. The emission spectrum was a broad one. Water is the main greenhouse gas as it absorbs a lot of energy.

So, some of the incident energy is reflected and a good part is absorbed. 50% is absorbed by earth's surface And of that overwhelmingly the ocean (lowest albedo). 20% is absorbed in the atmosphere. So, 30% is reflected back into outer space.

Heat budget of the Earth:

Incoming 100%

50% absorbed by the oceans

20% absorbed by the atmosphere

30% is reflected back into the outer space

Outgoing

Emission by the ocean- 10% net

- evaporation- in evaporation, energy that is in the molecules in the water kind of contributes to the quick outgoing of molecules into the atmosphere. That molecules is carrying a lot o energy. So, that little molecules is a little energy package. Also, when it condenses into a cloud, it will give away that heat. So, it's a very efficient way of transferring energy.

- radiation- black body radiation, would see glow of earth in that wavelengths.

(no real straight conduction from ocean to atmosphere. Don't see leaping streams of water moving into the ocean. You see conduction in the ocean and atmosphere, but at the boundary there is no easy way to transfer energy from one to the other, So it uses these two methods)

Emission by the atmosphere - 60%

-the atmosphere has its own budget of energy. The ocean passes some of it's energy from the oceans to the atmosphere. So, now it has two sources, from what it gets from the ocean and from the solar radiation.

Emission of heat flux. 30%

Inside of the earth is very hot, the outside is very cool. So, heat flows from hot portions to cool, so inside is continuously losing heat.

9% of heat is net loss of the oceans into the outer space. Then you have the emission of the atmosphere and that is 60%. 30% from the inside of the earth is lost to outer space.

**b. Describe what happens to incoming solar radiation as it relates to reflection, absorption, and photosynthesis**

The atmosphere is quite transparent to incoming short-wavelengths of the solar radiation. On an average, approximately 20 percent of the solar energy reaching the top of the atmosphere is absorbed at Earth's surface. Another 30 percent is reflected back into outer space by atmosphere, clouds, and reflect surfaces (snow, water). 5% is backscattered to space by the atmosphere. The remaining 20 percent is absorbed directly by clouds and the atmosphere's gases.

The solar radiation's wavelength and nature of the intervening material helped to determine whether the incoming solar radiation will be scattered, reflected, or absorbed. These percentages vary due to factors such as cloud cover (if the sky is overcast, a much higher percentage or light is going to be reflected back into space than if it is a clear, sunny day).

**c. Explain the mechanism and evaluate the significance of the greenhouse effect**

Approximately 50% of the incoming solar radiation is absorbed by earth's surface and absorbed. Most of this is reradiated back into space. Because earth has a much lower surface temperature, the wavelengths that it emits has longer wavelengths than solar radiation. Thus, the atmosphere is an efficient absorber of the longer wavelengths emitted by earth (called terrestrial radiation). Water vapor and carbon dioxide are the two principal absorbing gases, with water vapor absorbing five more than the other gases and accounts for the warm temperature in the troposphere. When the gases in the atmosphere absorbed terrestrial radiation, the gases warm up and eventually radiates this energy away. Some of this energy travels skyward to be reasboved by other gas molecules, or travel back down to be absorbed by the earth. Thus, the earth's surface is constantly being heating either through solar radiation from the sun or from the atmosphere. Without this heating from the atmosphere, life would not be suitable or habitable for humans or some life.

This phenomenon is known as the greenhouse effect. In short, greenhouse effect is caused by the gases, water vapor and carbon dioxide, which absorbs short-wavelengths and converts it to long-wavelength energy, which causes the wavelengths to now be trapped within the atmosphere and the earth.

**d. Differentiate among greenhouse conditions on Earth, Mars, and Venus; the origins of those conditions; and the climatic consequences of each**

**Greenhouse effect on Mars:** For much of it's first billion years of existence, it is thought that Mars was a warm and wet planet. Now, Mars appears to be a lifeless, frozen wasteland. Because Mars did have active volcanoes at one point, it is thought that the outgassing from the volcanoes helped provide atmospheric gas to form a thick atmosphere. Much of the gases from the volcanic eruptions were water vapors and carbon dioxide (similar to volcanic outgassing here on Earth), which would have warmed the planet. If the amount of gas produced by the volcanoes were similar to the amount on Earth, than Mars may have had enough water to fill oceans. Heat from meteorite impacts would have also helped release water vapor into the atmosphere, helping to enhance the greenhouse effect. At one point, carbon dioxide was lost and the greenhouse effect became weak until eventually the planet froze over. Some of the carbon dioxide condensed and froze to make the polar caps while others were bound to surface rock. The majority of the carbon dioxide was lost to space, although it is not clear as to why. One theory is that as Mars cooled, the magnetic field in the core (like on Earth), became weak as the core began to harden. Because the magnetic field became weak, the solar wind particles were able to strip the atmosphere and blow it into space.

**Greenhouse effect on Venus:** Why does Venus have such a strong greenhouse effect? Mainly, it's due to the large amounts of carbon dioxide in Venus' atmosphere, with approximately 96% of its atmosphere composed of carbon dioxide (200,000 times that of the Earth's atmosphere). However, we know that Earth and Venus have similar sizes and composition. So, what happened on Venus that allowed it to have such a high amount of carbon dioxide in its atmosphere. One main difference is that Venus has hardly any water. Another big difference is that Earth doesn't have a lot of carbon dioxide in its atmosphere. On earth, the ougassing of water from volcanoes condensed into rain, eventually forming the oceans. In addition, carbon dioxide on Earth dissolved in the ocean and eventually was locked away in rocks. It was measured that Earth has about 170,000 times as much carbon dioxide trapped in rocks than it has in its atmosphere. So, looking at the figures, we can see that Venus and Earth actually has the same amount of carbon dioxide. The difference is that on Venus, it is in a gaseous stage in the atmosphere whereas on Earth, it is stored in rocks. So, if all of the carbon dioxide was to be released into our atmosphere, then Earth would become as hot as Venus.

The other difference between Venus and Earth was water. Venus doesn't have much water on its planet. What little water was on Venus was baked away from the heat. Without any oceans on Venus, there was no way that carbon dioxide could dissolve and became trapped in the rocks. When water vapor was outgassed from volcanic eruptions, it is thought that the UV light from the sun broke apart the water molecules. The hydrogen atoms escaped into space and the oxygen atoms was lost to chemical reactions. Venus also had a weak magnetic field which left its atmosphere vulnerable to the sun's solar wind (similar to what happened with Mars). After billions of years of breaking water molecules down into oxygen and hydrogen, this prevented the formation of oceans on land, thus, prevented carbon dioxide from ever dissolving and being stored within rocks. The oceans, from the start would have never been able to fully form, or was evaporated quickly, due to the high amount of sunlight that Venus receives. Venus would be around 113 F, below boiling point. But, this high temperature would increase evaporation of water from the oceans (if there were any). There would be more water vapor in the atmosphere. And, since water vapor is a greenhouse gas, it would have helped strengthen the greenhouse effect. The greenhouse would have then warmed the planet even more, increasing evaporation and water vapors in the atmosphere, which would then strengthen greenhouse effect even more. This cycle Is known as the runaway greenhouse effect. This cycle would continue until there weren't any more oceans left on the planet.

Even if we were to move Venus to Earth's orbit, Venus would still not be just like Earth because of its weak magnetic field. There is so much controversy over WHY Venus has such a weak magnetic field. One though is due to the fact that it has a very slow rotation (243 days). Its rotation is just not fast enough to maintain a global magnetic field. Thus, without a magnetic field, solar wind is able to penetrate the atmosphere and blow hydrogen gas off into space. Another theory is that Venus' weak magnetic field doesn't really have to do with its slow rotation. Basically, we still do not know for sure the reasons as to why Venus does not have a magnetic field. If you are interested, there is a thread on physicsforum about this, or feel free to do more research on your own. :)

<http://www.physicsforums.com/showthread.php?t=344584>