Senior
UAK Earth as a System

Honors Class-"Earth as a System".

This would be a sophomore level Honors course, but would be suitable, with instructors permission, as a more advanced junior or senior level course for general students. The goals of the class would be to,

Identify the working machinery and to discuss the operation of the fundamental components of the earth system. Develop the necessary basic physics and chemistry needed.

Discuss the way in which the fundamental components interact with each other, using fundamentals from control system theory.

Examine and quantify the role of the human inpact on global geochemical cycles.

Draft outline of course entitled "Earth as a System"

Lecture 1-4 General discussion on global change.

5-10 Atmosphere: History of discovery of gases, size, structure, composition, vulnerability to change.

16a The planetary cloud system.

17. Oceans I
18. Oceans II
19. Geosphere (plate tectonics, volcanology, seismology).
20. Cryosphere: Snow, ice, permafrost, pack ice, glaciers, ice sheets
21 Biosphere: energetics, photosynthesis, mass and size spectra, chemical processes.
22. Biosphere II.
23. Examination I.

IV. <u>Climate and climate change.</u>(physical basis)

Purpose: To examine the physical basis for climate, to introduce elements of system control theory (feedbacks) and to discuss the historical record of Earth's climate.

24. Development of a pedagogical energy balance model (EBM) for the planet. Note: we will use a computer lab for this portion of the course.
25. EBM II Faint young sun paradox, greenhouse gas atmospheres, temperature-dependent albedos (daisy world).
26. EBM III, geochemical cycles
27. Concepts of system's engineering (control feedback theory), stability, sensitivities.

28. Control theory II
29. Feedback loops in the system: ice-albedo, water vapor-temperature, etc
30. Feedback through the planetary cloud system.

IV. Climate and Climate Change: the Observational Record

Purpose: Provide a perspective on the changing climate record.

31. Records of climate, proxy and otherwise
32. CT event and other catastrophic changes
33. Intermediate time scales, earth orbit alterations, ice ages
34. examination II

V. Change on Human Timescales

Purpose: Provide perspectives on human-driven global change issues and provide necessary background to make informed decisions relating to such issues.

35. Greenhouse gas (global warming)I
36. Greenhouse gas II
36a.Tropical deforestation
37. Climate change through aerosols/cloud
38. Ozone depletion
39. Acid rain/ air pollution issues
40. Human population
41. The issue of nuclear war.
42. Strategic themes for amelioration
43. Review

Notes on Energy Usage: Glenn E. Shaw, November 11, 1992

I have calculated energy use on a per capita basis for the United States and for some other countries as well, so we can get an intuitive idea of the order of magnitudes involved, and begin to understand what the flow of energy means and to begin a thought process on how to conserve. It was very difficult to make these calculations, because energy inventories are expressed in arcane units, for example in "million of barrels of oil per day", "cubic feet per second of natural gas", "millions of tons of hard coal", "British thermal units", "petajoules", "calories", "million tone of oil equivalent", "quadrillion BTU's", "Langleys per minute", "horsepower", "kilowatt hours", "eighteen wheelers", "ergs", "foot pounds", "pound inches", "electron volts", "equivalent number of bowls of wheaties", etc, etc. It is not so easy and fun to convert these bizarre units to something understandable, but I have attempted, in the tables below, to do so. Now, at long last, you have before you a uniform table of energy units!

Before getting into the "uniform tables", however, there are some interesting pearls that you may be interested in knowing:

* World energy consumption (1990) is 340 exajoules, of which more than one forth is consumed by the United States. An exajoule, by the way, is 10**18 Joules. Joule (pronounced like jewel) was a British engineer. The Joule is the unit of energy in the metric system

* I know you will become ecstatic to learn that one million tons of petroleum is equivalent, energywise, to 41,9 petajoules, or that the world consumption of natural gas is 277,000 cubic meters per second. These are the kinds of things I have converted for you in the "uniform table".

* The United States is the most energy inefficient country in the world. On a scale of USA consumption of energy being 100, other nation's energy usage is:

USA	100
UK	54
Sweden	52
Norway	71
Switz.	40
Australia	72
Japan	39
Argentina	20
Brazil	8
Bangladesh	0.7

* Total energy efficiency is to be an unbathed human being living in the tropics, plucking and gathering food and not cooking it. Such an "efficient system" consumes per capita energy of about 80 watts. We are, in other words, like little light bulbs. As a point of interest, I evaluated a new unit of energy "birthday candles". The average birthday candle (I bought some and measured the energy output) puts out 19 watts of heat and light energy. So four candles burning are like you and me, energy wise at least!

* For interest, you may wonder how the energy being consumed is generated. On a percentile basis its as follows:

Petroleum	37%	
Natural gas	21	
Coal	30	
Nuclear	5.5	
Hydro	6.6	
Other	1	(wind, solar, etc)

of those listed, coal and nuclear are increasing most rapidly. Petroleum is going to be on a declining curve. "other" may undergo increases, starting about a decade from now. What's missing in making "other" work? Lack of well directed science and engineering research.

* Now for the uniform table on energy expenditures. The unit of energy is kilowatts (1000 watts). This unit is "known by you" because you can work hard and exert a kilowatt of power for a brief time if you are young and strong. You coast through life expending about a tenth this power.

Per capita energy expended in USA	9.9 kw
UK	5.3
Japan	3.9
Argentina	2.0
Brazil	0.8
Bangladesh	0.07
World ave	2.7
Food sustenance	0.1
Consumption at $120 monthly GVEA bill	1.4
Ave consumption for 1 hot bath/day	0.3
Sun shining on one square meter	1.3
All the power put out by our star	10**23!

more will follow later....

FINAL EXAMINATION FOR HONORS COURSE IN GLOBAL CHANGE.

Autumn semester, 1992 Glenn Shaw

***This is a take home examination which you should do all by yourself. It is due at class on Monday, December 14, 1992.

This first question is a kind of order of magnitude or rough calculation just to see how you can do these things. I'm curious to see if you can do elementary logic and conversions of units.

I hope you know that a milliliter of water is the same as a cubic centimeter, that there are 10 mm per cm and that the density of water is 1 gram per cubic centimeter.

1. During our snowball fight, I put a bowl outside the Honor's house. About 30 snowflakes fell into it in 20 seconds of time. The bowl was 30 cm (about one foot) in diameter. After 11 minutes (during our snowball fight), the melt water was poured into a cylindrical jar. I measured the diameter of the jar (inside diameter) to be 5 cm and the water height to be 2 cm. Using these data (data is plural), do some rough calculations.

a. how many milliliters of meltwater did we collect?

b. what would be the weight of this water? (perhaps you remember that the metric system is so beautiful because one gram of wate occupies 1 cubic centimeter of space.

c. how many snowflakes fell into the bowl in the 11 minutes?

d. thus how much does a single snowflake weigh?

e. if you melted the snowflake into a droplet of water, how many cubic millimeters would it occupy?

f. what would the diameter of this droplet be?

g. if the snowflake formed by many cloud droplets coalescing together, and if cloud droplets are about 10 microns in diameter (0.010 mm), how many cloud droplets did it take to produce one of our giant snowflakes?

h. if the snowstorm affected, let us say, an area 3 times of Alaska, how much weight of water is falling per second? Per hour? Per day?

i. if it takes 0.6 "big" calories to evaporate one square centimeter of ocean water to produce the cloud that condensed to form the snowstorm 3 times as big as Alaska, then how much energy per second of time is expended?

j. if a person uses energy at the rate of 1000 calories per day, how many people could the energy of the snowstorm sustain, for at least the time it was snowing?

2. Let us say that Alaska is half covered with fairly dense spruce forest, like we see around Fairbanks.

estimate by some kind of method, how many trees that would be and how much they would weigh. Can you give me an idea of how much carbon dioxide (say in kilograms or metric tons=1000 kg) would enter the atmosphere if you burned these trees? Would this be a significant increase in the amount of carbon dioxide in the earth's atmosphere? The atmosphere is about 0.3% carbon dioxide, and has a mass of 4 x 10**15 kg. This notation means that it is 4, followed by 15 zeros!

3. Now for you English majors:

Kindly write several paragraphs in a little essay about the greenhouse effect. Tell it to an intelligent lay person, say, in a newspaper article. Don't forget to include the possible consequences. Of course convey what causes it, what it is, etc. Try to be succinct.

4. What is one of the serious problems associated with global change? Write a little essay about it, say a page or two long. Be certain to cover some of the dilemmas associated with the problem, such as ....well, you know what I mean.

Let me wish all of you my very best wishes as you go forward in life!! It was simply a spiritually-enriching experience to teach you and to be able to learn from you all. Let me know, as you go further into life, how these things in this class affect you.

Zen and The Natural Philosophy of a Snowstorm

Glenn E. Shaw

It was snowing hard one day. We, the Honor's class studying Global Change, decided to frolic.

During the snowball fight we placed a bowl outside the Honor's house and collected 36 grams of the falling snow in 11 minutes. There seemed to be around 90 flakes a minute falling into the one foot diameter bowl. They were humungous flakes of snow, about an inch across!

We can use this little exercise to glean some surprising insights into nature by making "order of magnitude" calculations.

It's straightforward to work out that the average weight of a snowflake is 36 milligrams. A flake would melt into a 4 mm droplet (about an eighth of an inch). Is this reasonable from from experience in watching rain pelt windshields?

Use the metric system for your calculations because of the simplicity: a cubic centimeter of water weighs a gram.

My friend Carl Benson told me, that though most countries have adopted the metric system, some nations like Zambia, Ethiopia and the United States of America reject the system and hold onto the "foot, pound, fortnight system".

Continuing on in our "order of magnitude calculations" on the snowstorm, we might assume that the storm is spread over a region about the size of Alaska (the weather map showed this to be about correct) and easily calculate that some 20 million tons of snow fall each second!! Remember, this is order of magnitude: the proper way would be so say that some tens of millions of tons are falling between clock ticks.

How can we get a grip on what this means? Well, the Tanana River seems about a half mile wide, and ,I guess, runs 15 feet deep and flows at a few miles per hour. Convert to metric units and make the simple calculation: one Tanana's worth of water flow is about 16,000 tons per second so we see that "one big snowstorm equals around a thousand Tanana's"!! That fills my heart with wonder!

One theory of snow formation is that droplets in a cloud coagulate together until they become large enough to fall out. Cloud drops are about a hundredth of a millimeter in diameter (and that in itself is worth thinking about: can you figure out a way to estimate this if I hadn't told you?). Our big snowflakes, it is easy to show by simple calculation, must involve a few tens of millions of cloud water droplets! This in itself is quite philosophical, and becomes deeply philosophical when you go to a slightly higher level of detail to show that that many droplets find it hard to coagulate together in the times involved (a few hours).

This is a little example of surprises that can come from pondering nature through order of magnitude. I am reminded of my father's story about the bumblebee: he can't fly, it turns out, at least according to the theory used for designing airplanes! Neither can clouds snow!

There are ways to overcome the theoretical difficulties in the "rainmaking process". They were discovered by the Swedish scientist Torr Bergeron in the 1930,s. But even with the new theory, we still find it difficult to "explain" rain (or snow).

My cloud physicist friend Sean Twomey always says "clouds find it hard to rain". It is becoming evident that global buildup of pollution will (or should!) have a significant effect on the hydrologic cycle and make it even harder for clouds to rain. Increasing desertification and drought surely are not forecasts to be welcomed from what we learned in our course!

The snowflakes falling on the Honor's house evaporated some hours earlier from the seas around Alaska. The amount of energy in the evaporation process is huge beyond imagination (almost). It would be the energy necessary to keep tens of millions of billions of people alive! Or....it would be equivalent to the kinetic energy expended by crashing 6 billion fully loaded 18 wheeler's wheeling down the highway at 60 miles per hour every second of time during the snowstorm!

Where does such enormous energy come from? Of course ultimately from the sun. That such enormous currents of energy flow all the time through our planet's thin skin is, again, I think, deeply philosophical.