Scientific Background to Global Environmental Problems
Spring 1993

Abbreviated Syllabus, with Approximate Dates

Week Beginning		Topic
Jan.	18	Overview: Biography of a Planet
	25	Continental Drift & Carbon Recycling; Review of Elementary Chemistry
Feb.	1	Review of Elementary Chemistry
	8	Radiation; Energy Balance & Planetary Surface Temperatures
	15	Meteorology; Planetary Atmospheric Histories; Molecular Radiation
	22	Photosynthesis; Greenhouse Warming & Climate Migration
Mar.	1	Stratospheric Ozone Depletion; Biological Effects
	8	SPRING BREAK
	15	Elementary Organic Chemistry
	22	*Elementary Biochemistry & Cellular Biology*
	29	Toxic Substances in the Environment; Bioremediation?
Apr.	5	Soil Microbiology; Biodegradation of Natural and Unnatural Waste Products
	12	Acid Precipitation: Sources & Complex Soil Chemistry Effects
	19	Acid Precipitation: Effects on Lakes, Forests, Crops.
	26	Biodiversity and Extinction of Species
May	3	Review

The supplementary texts (Gore and Lovelock) will cover only a small fraction of the subject matter of the course. Since no text is available which covers the necessary material, you will be provided with (voluminous!) class handouts as the semester progresses.

Problem sets will be due each week, at CLASSTIME on Fridays, and will be returned (hopefully) at the Monday afternoon discussion meetings. Since many of the problems will be numerical, you will need a simple hand calculator which is equipped with "scientific" or "exponential" readout. As much time as possible during these Monday sessions will be devoted to open discussions of current environmental problems, generally focussed on one of the chapters from Gore's book.

There will be (evening) hour exams on March 3 and April 14, each of which will count for 20% of the final grade. The problems will also count 20% and the Final 40%.

My office is in 5279 Chamberlin Hall (phone 262-1152), and you are welcome to stop by at any time.

To a man who knows nothing
Mountains are mountains
Water is water and
Trees are trees.
When he has studied and
knows a little,
Mountains are no longer
mountains
Water is no longer water and
Trees are no longer trees.
When he has thoroughly
understood,
Mountains are again
mountains
Water is water and
Trees are trees.

Anonymous

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Expanded Syllabus

1. Brief review of atoms, molecules, ions, isotopes; polar and non-polar bonds. Review of elementary math background, including logarithmic and exponential functions (half-lives and doubling-times), manipulations of powers of 10; Centigrade-Fahrenheit conversions.

2. Overview of blackbody radiation and spectrum, Stefan-Bolzmann and Wien Laws, power output of sun, radiation energy losses from planets; elementary calculation of surface temperature of moon via "power in = power out".

3. Overview of atomic energy levels and radiative transitions, Greenhouse Effect, dynamics of planetary atmospheres and glaciation.

4. Energy/work/power, with examples drawn from climatic phenomena; interconversion of energy units; molecular dissociation energies; endothermic photo-reactions (like photosynthesis); temperature and thermal energy; heat capacity (heat capacity of oceans $\approx$ 1000 times that of atmosphere, leading to thermal lag of climatic changes); total energy stored in coal, oil and gas reserves; solar power input to Earth; energetics of methanol as a transportation power source.

5. The Troposphere. Heat source at bottom of atmosphere $\rightarrow$ Greenhouse Effect and turbulence; adiabatic lapse rate and turbulence; tropopause; heat of condensation as a power source for cyclones; exponential atmospheric density falloff . 6. The Stratosphere and the Ozone Layer. Stability because heat source (solar radiation absorbed by O_3) is at top; O_3 absorption bands.

7. Comparative atmospheric histories of Venus, Earth and Mars; O_2 history on Earth and relation to biological evoluction. Escape velocity of molecules from planets and loss of H & He. Trapping of O_2 and CO_2 in rocks. Variation of $[CO_2]$ and $[CH_4]$ over geologic time: data from deep ice cores & use of ^{14}C dating.

8. Plate tectonics of Earth and vulcanism; continental drift (driven by heat

from decay of radioactive elements) and supercontinents; influences on paleoclimates; "processing" of CO_3-bearing sedimentary rocks as part of Carbon cycle, and relevance to CO_2Greenhouse Effect;

9. Elementary quantum physics of molecular energy levels and radiative transitions: rotations, vibrations and electronic transitions. Dissociation, ionization, polarizability. Long-wavelength (dipole) approximation to radiative decay rates for short antennas or small molecules. Molecular polarizability and IR-active and IR-inactive molecules. Normal modes of vibration of H_2O, $CO_2$and CH_4; explanation of why N_2 and O_2 have no Greenhouse effect, leaving it all to trace molecules like CO_2.Properties and spectra of O_3 & CFC's, and relevance to stratospheric O_3 depletion; absorption bands of DNA and their relation to those of O_3. CFC Greenhouse Effect from IR absorption at C-Cl bond.

10. Photosynthesis and Respiration. Carbon cycle, carbon and energy storage in plant biomass (forests vs. cultivated land). Climate of Carboniferous period, and accumulation of fossil fuels. [Energy/Carbon] storage ratios for coal, oil and natural gas. Fraction of solar power received which is currently being stored by photosynthesis. Is forest growth a feasible solution to the Global Warming problem?

11. Greenhouse Effect and Global Warming. Simple multi-layered, IR-absorbing atmosphere model as an example of a soluble mathematical model for the Earth: surface temperature $\propto$ fourth root of number of layers, which explains differing sensitivities to [CO_2] and [CFC's], as well as importance of "hole" in atmospheric absorption spectrum between 8μ and 12μ. Global warming feedbacks, such as melting ice and tundra. Global Climate Models. Climate migration and potential effects on natural ecosystems. Relevance of paleoclimate data, especially from recent glacial epochs. $[^2H/^1H]$ isotope ratio in deep ice cores as indicator of paleotemperature record over last 2×10^5 years.

12. Stratospheric O_3 Depletion. O_3 essential to life on Earth because of its absorption of UV radiation between .2 and .31 μ by its large photodissociation

cross section, which protects DNA molecules from UV damage. Ozone Hole: 70% of stratospheric O_3 disappears south of 70°S during September and October. Chemistry of catalytic O_3 distruction by Cl molecules from CFC's, importance of Polar Stratospheric Clouds. Effects on humans, plants and animals.

13. Acid Precipitation. Effects on forests, lakes, coastal wetlands, historic marble monuments. Acids formed by SO_2 and NO_2 from fossil fuel burned in power plants and motor vehicles. Tentative theories of mechanisms behind Waldsterben; proposed remedies.

14. Elementary concepts of Biochemistry. Organic molecules, photosynthesis and carbohydrates, lipids and (polar) cell membranes, proteins, enzymes and chelates.

15. Pollutants and Toxins in the Environment. Entry into organisms, metabolism and clearance. Mechanisms of toxicity: heavy metals, organic carcinogens. Pesticides, herbicides, fungicides. Possible remediation via inorganic degradation (mainly oxidation), biodegradation of organic molecules.

16. Biodiversity and Extinction of Species. Earth's accumulated Genetic Pool (10^9 Bits of information in typical mammalian DNA). Species diversity, genetic diversity; geologic rates of natural extinction compared with current anthropogenic rates. Causes: habitat destruction, soil exhaustion and erosion, pollution. Possible effects of global warming.

17. Gaia Hypothesis as an example of bio-feedback.