PUAF 741

Global Environmental Problems

FINAL EXAM

15 December 1994, 4:00–7:00 p.m., room 1107 VMH

Please enter your student number here: _____

This exam contains 100 points. Allocate your time accordingly (i.e., about 1.5 minutes per point).

This is a closed-book exam, except for one sheet of notes. The last page of the exam contains useful information (equations, constants, conversion factors, data, etc.). You may wish to separate that sheet from the exam to make its use more convenient.

Enter all answers and do your work directly on this exam in the space provided. Partial credit for incorrect answers can be given only if you show your work. If you need more space, use a blue book. Circle or underline final answers. If you need a number you can't find or derive, define a symbol for it and continue, or take a guess as to its value. If you don't have time to complete a problem but think you know how to do it, describe the steps.

Qualitative questions should be answered as precisely and succinctly as possible. Use the space provided; use a blue book if you need more space. *Make sure your handwriting is legible.* It is your responsibility, not mine, to ensure that I can read and understand your answer. Demonstrate a solid understanding of fundamental concepts; grammar is unimportant here.

When you are finished, turn in the exam along with any blue books that contain information you wish to be considered. Remember to write your student number, *not your name,* on everything you turn in.

Exam scores and course grades will be posted near my office door, rm. 4103 VMH, probably on Monday, 19 September. Good luck!

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1. According to ***World Resources***, energy consumption in China increased by 66 percent from 1971 to 1991, from 16.5 to 27.4 exajoules per year.

   A. What was the average annual rate of increase in energy consumption during this period, in percent per year? (4 points)

   B. If this trend continues, how long will it take for China's energy consumption to double? (3 points)

   C. U.S. energy consumption is 80.8 exajoules/yr. If China's energy consumption continues to grow at the 1971–91 rate, how long will it take for China to consume as much as the U.S. does today? (4 points)

   D. Population growth in China averaged 1.5 percent per year during the 1971–91 period. At what rate did *per-capita* consumption increase? (4 points)

2. You are working as a legislative aid for Senator Wackpood. The Senator would like you to explain why the Clean Air Act's provisions for limiting sulfur dioxide emissions will have only a minimal effect on the acid rain problem. The Senator has one minute to hear your case. (10 points)

3. Mexico City contains 15 million people and 2.5 million automobiles. The automobiles use leaded gasoline containing 0.6 grams of lead per liter. The average fuel efficiency of Mexican automobiles is 20 miles per gallon. In addition, assume that the average automobile is driven 20,000 kilometers per year.

   A. Estimate the rate at which lead flows into the Mexico City atmosphere from automobile emissions, in tonnes of lead per year. (5 points)

   B. The residence time of air in a city is roughly the time it takes for air, carried by the wind, to cross the city. The area of Mexico City is 522 square miles; the average wind speed is 6 miles per hour. What is the average residence time of air in Mexico City? (5 points)

   C. Using your answer to (B), calculate the average stock of lead in the Mexico City atmosphere, in kilograms. (5 points)

D. In order to calculate the *concentration* of lead, one must know not only the stock of lead but also the volume of air into which it is mixed. Mexico City suffers from frequent atmospheric inversions, during which pollution is trapped within 100 meters of the surface. Estimate the concentration of lead in Mexico City air in micrograms per cubic meter under these conditions. (HINT: your answer should be several times greater than the EPA standard of 1.5 $\mu g/m^3$.) (5 points)

E. The average five-year-old weighs 18 kg, contains 1.5 liters of blood, and breathes 10 cubic meters of air per day. Like adults, 48 percent of inhaled lead is absorbed directly from the lung into the bloodstream, where it remains with a residence time of 17 days. Another 15 percent is swallowed; 20 percent of this is absorbed from the GI tract into the bloodstream. Using your answer from (D), estimate the concentration of lead in the bloodstream of the average five-year-old, in micrograms per 100 milliliters. How does this compare with the levels which have been shown to cause various health effects in children? (5 points)

4. The IPCC has concluded that the average surface temperature of the Earth will rise by 1.5 to 5 °C if carbon dioxide concentrations double.

   A. What is the main source of uncertainty in the expected temperature increase? Explain briefly. (10 points)

   B. “Gee,” says Senator Bale Dumpers, “two or three degrees doesn’t seem like a lot. We might even benefit from a longer growing season and milder winters. A scientist told me that carbon dioxide was good for crops. Why should I be so worried about global warming?” (10 pts)

5. (15 points) In many developing countries, a significant fraction of energy use is in the form of biomass fuels (wood, crop waste, and dung) burned for cooking and heating. These biomass fuels contain both sulfur and nitrogen, and they are burned without emission controls. Investigate to what extent these practices could contribute to an acid rain problem in India, using the following assumptions:

   - biomass fuel use rate $\approx$ 1 te/yr per person for 600 million rural people;
   - biomass fuel composition = 4.7% N, 1.2% S by weight;
   - 100% of sulfur in fuel is emitted as SO_2;
   - 10% of nitrogen in fuel is emitted as NO_2;
   - 25% of SO_2 oxidized to sulfate and deposited in rain;
   - 50% of NO_2 deposited in rain;
   - each mole of S in rain leads to 2 moles of H^+ in rain;
   - each mole of N in rain leads to 1 mole of H^+ in rain;
   - all other sources of acid can be ignored;
   - precipitation = 1 meter per year over land area of 3 million km^2;
   - pre-industrial pH of regional rain = 6.

6. Write a very short paper, in the form of “talking points” for a congressperson, describing the stratospheric ozone problem. (15 points)

POSSIBLY USEFUL INFORMATION

$S = F \cdot \tau$

(stock) = (flow) x (residence time)

1 te = 1000 kg

1 mi = 1609 m = 5280 ft

1 ft = 0.3048 m = 12 in

1 in = 2.54 cm

1 m = 39.4 in

1 gal = 3.754 L

$1\ m^3 = 1000\ L$

$P = 4\sigma T^4$; $\sigma = 5.67 \cdot 10^{-8}\ W/m^2K^4$

$K = °C + 273$

Distance = (velocity) x (time)

$S(t) = S(0)\ e^{rt}$

$S(t) = S(0) \cdot (1 + i)^t$

Density of water = $1\ te/m^3 = 1\ g/cm^3$

Mass of average adult male = 70 kg

Blood mass of average adult male = 5.5 kg

Surface area of Earth = $510 \cdot 10^6\ km^2$

$pH = -\log_{10}[H^+]$

$[H^+]$ = moles of H^+ per liter of water

$1\ yr = 3.155 \cdot 10^7\ s$

Solar "constant" = $1372\ W/m^2$

$Z = (x_1 - x_2)/(\sigma_1^2 + \sigma_2^2)^{½}$; $\sigma \approx p(1 - p)/N$

Volume = (area) x (height)

$rT_2 \approx 69$

800 cancer deaths per million person-rem delivered in less than one week