

PUAF 741

Global Environmental Problems

FINAL EXAM

18 December 1997, 4–7 pm, room 1206 VMH

Please enter your student number here: _____

Begin by reading the entire exam. Do the easiest problems first.

This exam contains 100 points. Allocate your time accordingly (i.e., about 9 minutes per 5-point problem).

This is a closed-book exam, except for one sheet of notes. Possibly useful information is attached. Calculators are allowed; computers are not.

Enter all answers and do all your work on this exam. If you need more space, use the other side of the sheet.

Quantitative questions should include an appropriate number of significant digits, together with the proper units. **Circle final answers.** Partial credit for incorrect answers can be given only if you show your work, *and only if your handwriting is legible.* If you need a number you can't find or derive, define a symbol for it or take a guess as to its value and continue. If you don't have time to complete a problem but think you know how to do it, describe the steps. If you believe that I haven't given you enough information to answer the question, ask me about it.

Qualitative questions should be answered as precisely and succinctly as possible. *Make sure your handwriting is legible.* Style is less important here.

Exam scores and course grades will be posted near my office, 4103 VMH, no later than Monday, 22 December.

Good luck!

1. Coal consumption in India was 3309 and 6140 PJ/yr in 1983 and 1993, respectively.

A. Estimate the average annual growth rate of coal consumption. (5 pts)

B. Indian coal has an average energy content of 26 MJ/kg and an average sulfur content of 2 percent by weight. How much sulfur was emitted by Indian coal burning in 1993, in Mte? Compare this to the 9 Mte(S) emitted by the United States in the same year. (5 points)

C. How much sulfur would India emit in 2013 if the consumption of coal continues to grow at the 1983-93 rate? (5 points)

2. The population of Belgium is about 10 million. The population growth rate has been very close to zero for several decades. Estimate the number births and deaths in Belgium each year. [HINT: stock, flow, residence time.] (5 points)

3. Fluorescent lighting is much more efficient than incandescent, using one-fourth the electricity to deliver the same amount of light. In the U.S., about 7 percent of electricity is used for incandescent lighting. Electricity production is responsible for 35 percent of U.S. carbon emissions. If all incandescent lights were replaced by fluorescents, by about what percentage would U.S. emissions of carbon dioxide be reduced? (5 pts)

4. Lake Morbid, in the coal-mining region of Lower Slobovia, has a surface area of 500 hectares and an average depth of 20 meters. The lake is the source of Coal Creek, which has an average flow at this point of 1.6 cubic meters per second. The surrounding mines discharge an average of 1 tonne per day of mine acid (i.e., sulfuric acid, H_2SO_4) into the lake.

A. What is the flow rate of acid into the lake in moles per year? (5 pts)

B. Calculate the stock of acid in the lake, in moles. What assumption did you make to do this calculation? (5 points)

C. Estimate the pH of the lake water, assuming that the mine acid is the only source of H^+ ion. (5 points)

5. Some have suggested using liquid fuels derived from biomass as substitutes for fuels derived from oil. In the U.S., the highest yielding crop is sorghum—about 19 tons of dry biomass per hectare per year. The energy content is about 17.5 MJ per kilogram of dry biomass, 90 percent of which can be captured in the form of ethanol.

A. How much land would be required to offset U.S. oil imports, which in 1993 totaled 2,457 million barrels (Mbbbl)? How does this compare with the total amount of cropland harvested (300 million acres)? The energy content of petroleum is 6.1 GJ/bbl. (10 points)

B. The market price of sorghum is about ten cents per pound. Translate this into dollars per gigajoule, and compare it to the current price of oil (about \$20 per barrel). (10 points)

6. A key feature of the climate-change issue is that several substances released by humans influence global climate.

A. List the substances that influence climate and the human activities that give rise to these emissions. (5 points)

B. The effect of emissions on climate is often measured in terms of their “instantaneous radiative forcing.” What is this? Why is radiative forcing an inadequate basis for comparing the potential climate effects of different types of emissions? (5 points)

POSSIBLY USEFUL INFORMATION

1 meter (m) = 3.281 feet (ft)	1 mole(gas) = 22.4 L @ STP
1 mile (mi) = 1609 m = 5280 ft	1 hour (hr) = 3600 seconds (s)
1 hectare (ha) = 10^4 m^2 = 2.47 acres	1 year (yr) = $3.155 \cdot 10^7 \text{ s}$
1 m^3 = 1000 liter (L) = 1 te(H_2O)	1 Joule (J) = $\text{kg} \cdot \text{m}^2/\text{s}^2$
1 gallon (gal) = 3.754 L	1 BTU = 1055 J
1 barrel (bbl) = 42 gal	1 kilowatt-hour (kWh) = 3.6 MJ
1 kilogram (kg) = 2.205 pounds (lb)	1 Watt (W) = 1 J/s
1 tonne (te) = 1000 kg	1 horsepower (hp) = 746 W
1 mole = $6.02 \cdot 10^{23}$ molecules	Kelvin (K) = degrees Celsius + 273

$S = F \cdot \tau$	$\text{pH} = -\log_{10}[\text{H}^+]$
$S(t) = S(0) \cdot e^{rt} = S(0) \cdot (1 + i)^t$	$[\text{H}^+] = \text{moles}(\text{H}^+) \text{ per liter } \text{H}_2\text{O}$
$i = [S(t)/S(0)]^{1/t} - 1 = e^r$	area of Earth = $5.10 \cdot 10^{14} \text{ m}^2$
$r = \ln[S(t)/S(0)]/t = \ln(1+i)$	mass of atmosphere = $5.14 \cdot 10^{18} \text{ kg}$
$\log(a \cdot b) = \log(a) + \log(b)$	moles of dry air = $1.78 \cdot 10^{20}$

$k = 10^3$; $M = 10^6$; $G = 10^9$; $T = 10^{12}$; $P = 10^{15}$; $E = 10^{18}$
 $m = 10^{-3}$; $\mu = 10^{-6}$; $n = 10^{-9}$; $p = 10^{-12}$; $f = 10^{-15}$; $a = 10^{-18}$

Atomic weights: H = 1; C = 12; N = 14; O = 16; S = 32
