

PUAF 741

Global Environmental Problems

FINAL EXAM

Monday, 17 May 2004, 4–7 pm, room 1207 VMH

Enter your UMCP student number here: - -

Do not enter your name anywhere on this exam (5-point penalty!)

This exam contains 100 points. You have three hours to complete the exam. Allocate your time accordingly (i.e., 9 minutes per 5-point problem).

This is a closed-book exam, except for one sheet of notes. 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 back side of the sheet.

Quantitative questions should include an appropriate number of significant digits and the proper units. **Circle final answers.** Partial credit for incorrect answers can be given only if you show your work. 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 know your answer is wrong, say so. If you're uncertain about the nature of the question, ask me.

Qualitative questions should be answered as precisely and succinctly as possible. Complete, polished sentences are not necessary, but **your handwriting must be legible.**

Exam scores and course grades will be posted on the course web site no later than Wednesday afternoon.

Good luck!

1. True or false (10 points total):

- | | | |
|--|------|-------|
| A. If the rate of consumption is growing exponentially, consumption in next doubling period equals all previous consumption. | True | False |
| B. Carbon dioxide is the chief greenhouse gas in the atmosphere. | True | False |
| C. In general, low clouds warm and high clouds cool the atmosphere. | True | False |
| D. Uncertainty in climate models has steadily decreased with time. | True | False |
| E. Sea level has risen from melting of sea ice in the Arctic Ocean. | True | False |
| F. It is estimated that 90% of all species are found in the tropics. | True | False |
| G. As a result of Title IV of the 1990 amendments to the Clean Air Act, emissions of nitrates decreased about 50 percent. | True | False |
| H. All elements heavier than lithium were created in stars. | True | False |
| I. All else equal, ecosystems with greater diversity are generally more productive and more stable to environmental change. | True | False |
| J. In species-area relationships, the exponent z gives the change in the number of species for a 1 percent change in ecosystem area. | True | False |

2. Circle the correct numbers, words, or phrases (10 points total):

- A. The current concentration of CO_2 is about (275, 325, 375, 450) ppmv.
- B. The population of the US is about (250, 300, 350, 400) million.
- C. If $\Delta T = 2.5^\circ\text{C}$ from a doubling of CO_2 , then ΔT from a quadrupling of CO_2 would be roughly (2.5, 5, 7.5, 10) $^\circ\text{C}$.
- D. If we stabilize emissions of CO_2 , the atmospheric concentration of CO_2 will (fall; remain constant; rise for a while then stabilize; keep rising forever).
- E. The pH of pristine rainfall is about (5.0, 5.5, 6.0, 6.5, 7.0).
- F. The principle source of acidity in natural rainfall is (OH^- , SO_2 , CO_2 , SO_4^{2-}).
- G. In $\text{pH} = -\log_{10}[\text{H}^+]$, $[\text{H}^+]$ is in units of (g/g, g/mole, g/L, mole/g, mole/mole, mole/L)
- H. Approximately (2, 5, 10, 14, 30, 100) million species have been identified.
- I. In countries with stable populations the birth rate is approximately (4, 7, 10, 13) per thousand people per year.
- J. World population estimates for 2050 have fallen steadily over the last 20 years has result of unexpected (decreases in fertility, increases in death rate).

3. The latest IPCC report concludes that climate is warming, and that this warming is due at least in part to human emissions of greenhouse gases. This conclusion is based not simply on the observed increase in global average temperature, but on the observed pattern of this warming.

A. What pattern of warming would you expect to result from an increase in greenhouse gas concentrations? (5 points)

B. What observations, other than temperature, are consistent with greenhouse-gas-induced climate change? (5 points)

4. According to BP, total energy consumption in China increased from 441 million tons of oil equivalent (TOE) in 1982 to 998 million TOE in 2002.
- A. What was the average growth rate, in percent per year, over this 20-year period? (4 points)
- B. During this period the population of China grew at an average rate of 1.0 percent per year, from 1050 to 1280 million. What was the average growth rate of per-capita energy consumption? (2 points)
- C. If per-capita consumption in China continues at the average 1982-2002 rate, in what year would it reach the current U.S. level of 8 TOE/y? (4 points)

5. The preindustrial atmospheric concentration of methane (CH_4) was stable for thousands of years at about 700 parts per billion. The residence time of methane in the atmosphere is about 12 years.

A. What is the natural (i.e., preindustrial) flow of methane into the atmosphere, in millions of metric tons of CH_4 per year? (5 points)

B. Anthropogenic emissions of methane are currently estimated at 400 million tons of CH_4 per year. If emissions were stabilized at this level, what would be the steady-state concentration of methane? (5 points)

6. Today, the cost of producing electricity in a new nuclear reactor is estimated to be about \$0.065/kWh, compared to \$0.045/kWh for a new coal plant. What carbon tax (in dollars per metric ton of carbon) would be required to make nuclear economically competitive with coal? Assume coal is 75% carbon by weight, has a heat energy content of 29 MJ/kg, and that heat energy is converted to electrical energy with an efficiency of 40 percent in a new coal plant. (15 pts)

7. In the early 1970s, NASA examined the effect of a fleet of 500 supersonic transports on the ozone layer. It was assumed that each SST made four transatlantic flights per day, spending two hours in the stratosphere during each flight and burning fuel at a rate of 20 tons per hour. NASA estimated that 15 grams of nitric oxide (NO) would be emitted per kilogram of fuel burned. Nitric oxide is a potent catalyst for ozone destruction; each NO molecule would, on average, catalyze the destruction of roughly 10,000 ozone molecules during its residence time in the stratosphere.
- A. Estimate the steady-state rate of ozone destruction, in gigatons per year, resulting from the operation of the fleet of SSTs. (10 pts)

- B. Estimate, very roughly, the corresponding percentage decrease in the stratospheric ozone concentration, assuming that the rate of natural production is 160 Gt/y. (5 pts)

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 (h) = 3600 seconds (s)

1 hectare (ha) = 10^4 m^2 = 2.47 acres

1 year (y) = $3.155 \cdot 10^7 \text{ s}$

1 m^3 = 1000 liter (L) = 1 t(H_2O)

1 joule (J) = $\text{kg} \cdot \text{m}^2/\text{s}^2$

1 gallon (gal) = 3.785 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 metric ton (t) = 1000 kg

1 horsepower (hp) = 746 W

1 mole = $6.02 \cdot 10^{23}$ molecules

Kelvin (K) = degrees Celsius + 273

$$S = F \cdot \tau \quad c = S/V$$

$$\text{area of Earth} = 5.10 \cdot 10^{14} \text{ m}^2$$

$$S(t) = S_0 e^{rt} = S_0(1 + i)^t$$

$$\text{mass of oceans} = 1.35 \cdot 10^{21} \text{ kg}$$

$$i = [S(t)/S_0]^{1/t} - 1 = e^r - 1$$

$$(1 - \alpha) \pi R^2 \Omega = 4\pi R^2 \sigma T^4$$

$$r = \ln[S(t)/S_0]/t = \ln(1+i)$$

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

$$T_{2X} = 0.69/r$$

$$\Omega = 1370 \text{ W/m}^2$$

$$S(t) = F_0(e^{rt} - 1)/r$$

$$\Delta T = (\Delta F/3.7) \Delta T_{2X}$$

$$T = \ln[rS(t)/F_0 + 1]/r$$

$$\Delta F_{\text{CO}_2} = 5.35 \ln(C/C_0) \text{ W/m}^2$$

$$\ln(a \cdot b) = \ln(a) + \ln(b)$$

$$\text{mass of atmosphere} = 5.14 \cdot 10^{18} \text{ kg}$$

$$e^a e^b = e^{(a+b)}$$

$$\text{moles of dry air} = 1.78 \cdot 10^{20}$$

$$\text{pH} = -\log_{10}[\text{H}^+] \quad [\text{H}^+] = \text{moles}(\text{H}^+) \text{ per liter}$$

$$\text{gravitational acceleration} = g = 9.8 \text{ m/s}^2$$

$$S = cA^z = S_0(A/A_0)^z$$

$$\text{energy} = mgh = \frac{1}{2}mv^2 = mCT$$

$$h = 10^2; \quad k = 10^3; \quad M = 10^6; \quad G = 10^9; \quad T = 10^{12}; \quad P = 10^{15}; \quad E = 10^{18}$$

$$c = 10^{-2}; \quad m = 10^{-3}; \quad \mu = 10^{-6}; \quad n = 10^{-9}; \quad p = 10^{-12}; \quad f = 10^{-15}; \quad a = 10^{-18}$$

Atomic weights: H = 1; C = 12; N = 14; O = 16; S = 32; Ca = 40 g/mole