PUAF 741

Global Environmental Problems

FINAL EXAM

Tuesday, 19 May 2003, 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 hand-writing must be legible.**

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

Good luck!

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1. True or false (8 points):

When global-average total fertility rate reaches the replacement level (2.1 lives births per woman), global population will stop growing.	True	False
If we stabilize anthropogenic emissions of CO_2 at current levels, the concentration of CO_2 will eventually stabilize.	True	False
If we stabilize anthropogenic emissions of CH_4 at current levels, the concentration of CH_4 will eventually stabilize.	True	False
The main uncertainty in population projections is due to uncertainty in future mortality rates.	True	False
The cost of compliance with the Montreal Protocol and Title IV of the Clean Air Act have proved to be significantly less than first estimated.	True	False
The Adirondacks is the region most affected by acid rain because it receives the most acidic rainfall in the United States.	True	False
Sulfuric acid produced during the burning of coal is the main source of acid deposition in Southern California.	True	False
The surface temperature of Earth increases as the albedo increases.	True	False

2. Circle the correct numbers, words, or phrases (9 points):

   A. The observed change in temperature has been greatest at: (high, low) latitudes; during (summer, winter); during (daytime, nighttime).

   B. The current global population is about (4, 5, 6, 7, 8) billion.

   C. Acid precursors include (SO_2, CO, NO, CFCs, CO_2, NO_2, CH_4, NH_3, O_3).

   D. If we stabilize concentrations of CO_2, global-average surface temperature will (fall; remain constant; rise for a while then stabilize; keep rising forever).

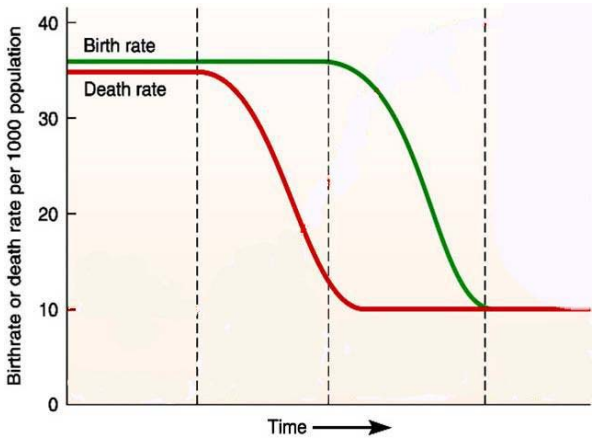
   E. As a result of increased global efforts to control emissions of acid precursors, the IPCC recently revised (upward, downward) its estimates of global-average temperature change over the next century.

   F. The global thermohaline circulation is driven by the formation in the North Atlantic of water that is (colder, warmer) and (more, less) salty, which then (rises to the top, sinks to the bottom) of the ocean.

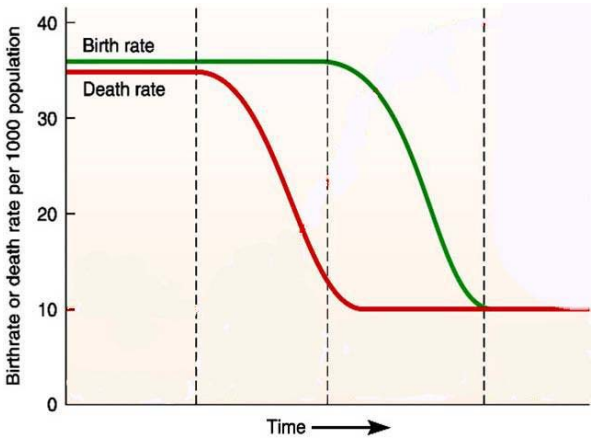
   G. An ozone hole has opened over the (north, south) pole each (October, April) causing up to (25, 60, 90) percent depletion of ozone.

3. A model predicts that a tax of $25 per metric ton of CO_2 is needed to meet the emission reductions required by the Kyoto Protocol. Express this tax in dollars per gallon of gasoline. Assume gasoline has a density of 0.75 kg/L and is 85% carbon by weight. (6 pts)

4. The notional graph below illustrates the demographic transition. (4 pts)



A. Sketch the population growth rate as a function of time.



B. Sketch the total population size. What is the shape of this curve?

5. As required by the UNFCC, the US reported total emissions of CO_2 of 4,998,516 gigagrams in 1990 and 5,840,039 gigagrams in 2000.

   A. At what average annual rate did emissions grow during this period? (5 pts)

   B. During this period, US population grew at an average rate of 1%/y and per-capita GDP grew at an average rate of 2%/y. What was the average rate of change of "emissions intensity" (CO_2 emissions per dollar of GDP)? (5 pts)

   C. After it renounced Kyoto, the Bush administration adopted a goal of reducing the emissions intensity of the US economy by 18 percent over 10 years. How does this goal compare with the experience in the 1990-2000 period? (5 pts)

6. Acid mine drainage (AMD) is a major environmental problem in many areas. AMD results primarily from the oxidation of iron pyrite (FeS_2) contained in the ores from which minerals are extracted, by groundwater flowing through abandoned mines:

$$FeS_2 + 7/2\ H_2O + 15/4\ O_2 \rightarrow Fe(OH)_3 + 4H^+ + 2SO_4^{2-}$$

   A. AMD from a mine has an average sulfate (SO_4^{2-}) concentration of 150 milligrams per liter. Considering only the reaction above, what is the pH? (5 pts)

   B. Precipitation in the area averages 100 cm/y; of this, 35 cm goes into the groundwater. The abandoned mine covers an area of 100 ha. All groundwater percolating through this area is AMD. Based on your answer to part A, what is the total outflow of $[H^+]$ in the AMD, in moles per year? (6 pts)

C. The AMD drains into a lake with a volume of 20 billion liters. The residence time of water in the lake is 2 years. If AMD is the only source of $[H^+]$, what is the pH of the lake water? (6 pts)

7. In 1992, Harvard biologist E.O. Wilson estimated the rate of species extinctions in the tropics, assuming 10 million species endemic to the tropical forest, that tropical forest was being lost to deforestation at a rate of 1.8 percent per year, and a slope for the species-area relationship, z = 0.15. What was his estimate of the number of species extinctions per year? (5 pts)

8. Anthropogenic emissions of nitrous oxide (N_2O) are about 8 Tg/y, mostly from agricultural soils and wastes. N_2O is unreactive in the troposphere; it diffuses into the stratosphere, where it is broken down by ultraviolet radiation into nitric oxide (NO):

$$2N_2O + h\nu \rightarrow 2NO + N_2$$

A. NO is highly reactive; each molecule catalytically destroys approximately 1,000 ozone molecules during its residence time in the stratosphere. If emissions remain constant at 8 Tg/y, what will be the steady-state rate of ozone destruction from anthropogenic emissions of N_2O, in molecules per year? (6 pts)

B. The natural (preindustrial) rate of ozone production/destruction is about $2 \cdot 10^{39}$ molecules/y. Roughly what percent depletion in the ozone stock you would expect to result from anthropogenic emissions of N_2O? What do you conclude? (5 pts)

9. Give one example of a positive climate feedback mechanism, and one example of a negative feedback mechanism, and briefly explain how they operates. (6 pts)

10. In some regions, acid precipitation has a devastating effect on freshwater ecosystems. In other regions, equally acidic precipitation has little or no effect. What accounts for the difference? (4 pts)

11. Briefly describe five examples of linkages (in science or policy) between the problems discussed in this course (climate change, ozone depletion, acid rain, biodiversity loss). Each problem must be mentioned at least once. (15 pts)

POSSIBLY USEFUL INFORMATION

1 meter (m) = 3.281 feet (ft)

1 mile (mi) = 1609 m = 5280 ft

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

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

1 gallon (gal) = 3.785 L

1 barrel (bbl) = 42 gal

1 kilogram (kg) = 2.205 pounds (lb)

1 metric ton (t) = 1000 kg

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

1 mole(gas) = 22.4 L @ STP

1 hour (h) = 3600 seconds (s)

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

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

1 BTU = 1055 J

1 kilowatt-hour (kWh) = 3.6 MJ

1 watt (W) = 1 J/s

1 horsepower (hp) = 746 W

Kelvin (K) = degrees Celsius + 273

$S = F \cdot \tau$

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

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

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

$T_{2X} = 0.69/r$

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

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

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

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

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

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

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

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

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

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

Ω = 1370 W/m^2

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

$\Delta F_{CO2} = 5.35 \ln(C/C_0)$ W/m^2

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

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

gravitational acceleration = g = 9.8 m/s^2

energy = mgh = ½mv^2 = mCT

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

c = 10^{-2}; m = 10^{-3}; μ = 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; Ca = 40 g/mole

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