

PUAF 741

Global Environmental Problems

FINAL EXAM

Tuesday, 14 December 1999, 6:00–10:00 pm, room 1206 VMH

Please enter your student number here: _____
Do not enter your name anywhere on this exam!

Read this page first, then review the entire exam. Answer the easiest questions first.

This exam contains 100 points. You have 3 hours to complete the exam. Allocate your time accordingly (about 15 minutes per 10-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 and 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 know your answer is incorrect, let me know. If you are confused by a problem or believe that you need more information, 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. If I can't read it, I can't grade it!

Exam scores and course grades will be posted on the course web site.

Good luck!

6. The Exxon Valdez spilled 11 million gallons of crude oil into Prince William Sound (PWS), which has an area of $8,800 \text{ km}^2$ and an average depth of 300 m.
- A. Six of the 11 million gallons were recovered in the vicinity of the ship. Before tidal currents began to flush the oil out to sea, about half the area of PWS was covered with the remaining oil. What was the average thickness of the slick? (5 points)

B. In reality, by the time the slick covered half of PWS wave action mixed the oil into the top 10 meters of water. What was the average concentration of oil in these surface waters, in parts per billion by weight? Alaska's water quality standard is 10 ppb; concentrations above 100 ppb are toxic to most marine life. (6 points)

C. Exxon paid \$2.5 billion for clean-up, \$300 million in claims, and \$5 billion in punitive damages. If this is charged to the total amount of oil that has been pumped through the Alaskan pipeline (about 11 billion barrels), roughly how much would this increase the price of gasoline made from this oil? (5 points)

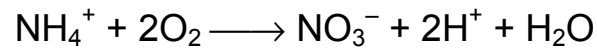
7. When considering the energy balance of the Earth, we assumed that the rate at which infrared energy is radiated to space is equal to the rate at which solar energy is absorbed.

A. What is this average rate of energy absorption/radiation, in W/m^2 ?
(5 points)

D. The current rate of fossil and nuclear energy production is about 400 EJ/yr. Compare this rate, in W/m^2 , to the change in the energy balance expected from a doubling of the CO_2 concentration. What do you conclude? (5 points)

E. Over the last century, energy consumption has grown at an average rate of about 3.5 percent per year. If it continued to grow at this rate for the next century, what would the rate of human energy use be in W/m^2 ? Would the resulting heat, if derived largely from fossil, nuclear, or geothermal sources, then be of climate concern? Do you consider this scenario likely? (5 pts)

8. As noted in class, there are natural as well as anthropogenic sources of acidity. Nitrification—the conversion of ammonium (from decay) to nitrate (the more usable nutrient form)—is one such source of acidity:



The rate of nitrification in freshwater lakes typically is about 10^{-4} moles of nitrogen per liter per year. Consider a lake with an area of 1 km^2 and an average depth of 100 m, with a stream outflow of $550,000 \text{ m}^3/\text{d}$.

- A. Considering only the above reaction (i.e., nitrification is the only source of H^+ and there are no neutralizing bases), what would the equilibrium pH of the lake be? (10 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) = $3.155 \cdot 10^7$ s
1 m ³ = 1000 liter (L) = 1 te(H ₂ O)	1 Joule (J) = kg·m ² /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

$S = F \cdot \tau$	mass of oceans = $1.35 \cdot 10^{21}$ kg
$S(t) = S(0) \cdot e^{rt} = S(0) \cdot (1 + i)^t$	$(1 - \alpha) \pi R^2 \Omega = 4\pi R^2 \sigma T^4$
$i = [S(t)/S(0)]^{1/t} - 1 = e^r$	$\sigma = 5.67 \cdot 10^{-8}$ W/m ² K ⁴
$r = \ln[S(t)/S(0)]/t = \ln(1+i)$	$\Omega = 1370$ W/m ²
$\log(a \cdot b) = \log(a) + \log(b)$	$\Delta T = \lambda \Delta F$; $\lambda = 0.3$ to 1 K/(W/m ²)
$\text{pH} = -\log_{10}[\text{H}^+]$	$\Delta F_{\text{CO}_2} = 6.3 \log_e (C/C_0)$ W/m ²
$[\text{H}^+] = \text{moles}(\text{H}^+) \text{ per liter } \text{H}_2\text{O}$	mass of atmos. = $5.14 \cdot 10^{18}$ kg
area of Earth = $5.10 \cdot 10^{14}$ m ²	moles of dry air = $1.78 \cdot 10^{20}$

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

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