Physics 104 | **Environmental Physics**
2. Exam | **March 14, 2002**

Name: ________________________________

Salinity of the Oceans:

a) Why are oceans salty? (2 points)
Erosion of rocks and sediments carries dissolved ions into the oceans, where they accumulate.

b) What is the average salinity of the oceans? (1 point)
About 35 ‰.

c) What causes local differences in salinity? Please provide examples. (5 points)
I) Excessive evaporation concentrates salt in the remaining water and increases salinity, ii) low evaporation combined with influx of large amounts of fresh water can cause relatively fresh oceans. iii) Sea ice generation is another way to increase salinity locally. Examples: I) Mediterranean, ii) Baltic Sea, iii) North Atlantic, Antarctica others may count as well

Heating of Oceans and Atmosphere (4 points)
Compare how the atmosphere and oceans are heated respectively and discuss the effect on the convection of the oceans.

The troposphere is heated from below by IR radiation given off by the land or ocean surfaces. It is cooled from the top by radiating heat into space. It is unstable because warm, low density air is generated at the bottom of the atmosphere, which tends to rise to the top of the atmosphere.
Oceans are heated from the top by interaction with sunlight. They are thermally stable and therefore stratified because warm, low density water tends to sit on top of cold dense water.

How does the Coriolis Effect reinforce wind-driven gyres? (10 points)

Hint: I expect a detailed answer!
Trade Winds and Westerlies drag water along their path, causing surface water currents that move towards the W near the equator and towards the E in the mid-latitudes. Interaction of these currents with continents sets up a wind driven gyre system. Coriolis forces, however, tend to deflect water masses to the right (on N - hemisphere), causing a deflection to the right of the surface water current by 20 - 45°. The surface water interacts with water deeper below and drags it along. The Coriolis force, again, causes this deeper water to be deflected by 20-45° to the right with respect to the surface water, or about 40-90° with respect to the original wind current. Consequently, deeper water layers are moving at larger and larger offset angles, causing a ***net-transport*** *of surface water at 90° to the original wind current into the center of the gyre where it piles up. The surface water tends to flow out of the gyre, but is again, deflected to the right by the*

Coriolis force, causing a geostrophic flow, which reinforces the original wind-driven gyre.

Oceanic Bottom Water Formation

a) In the cross section below sketch the approximate temperature distribution of the Atlantic. Where would you expect the generation of bottom water? (3 points)
See fig. 9-8a in Kump et al.

b) Which processes lead to the formation of bottom water, where does bottom water formation occur? (3 points)
Generation of dense (= cold and saline) water, it occurs at high latitudes where sea ice formation concentrates salt in the remaining cold water and makes it sink. The main places for this to occur are the North Atlantic and the Weddell Sea.

c) Where does bottom water reemerge at the ocean surface? (2 points)
In divergence zones, e.g., at the margins of continents or between gyres near the equator.

El Niño (4 points)
Briefly describe the physical causes of El Niño and describe **one** effect on global climate.
In normal years, strong trade winds cause the accumulation of warm surface water in the Western Pacific (Western Pacific Warm Pool), which leads to the upwelling of cold nutrient rich waters in the Eastern pacific, especially at the coast of S-America. In El Nino years the trades break down and warm, nutrient depleted water moves back eastward, capping cold upwelling water and affecting the climatic balance of the atmosphere.
Any climatic result discussed in the papers, in class or in your homework assignments will do.

Timescales
What are characteristic timescales for (rough estimate, no exact numbers necessary)

a)	the atmosphere	(1 point)	*weeks to months*
b)	the oceans	(1 point)	*thousands of years*
c)	the solid earth?	(1 point)	*millions of years*

Residence time of CO_2 in the atmosphere: (4 points)
The atmosphere holds approximately 760 Gt (giga tons = 10^9 tons) of carbon. Assuming a steady state of atmospheric carbon concentrations (which ignores anthropogenic carbon input) and an annual input/outflow of 60 Gt of carbon / year: what is the residence time of carbon in the atmosphere?
Hint: The residence time is the same time it takes to fill an originally empty atmosphere to its present level of 760 Gt.

Residence time = Reservoir size / input (output) rate

$$T = \frac{760\,Gt}{60\,Gt\,/\,yr} = 13\,years$$

Influence of Oceans on Atmosphere

a) How can small changes in the state of the ocean severely affect the CO_2 concentration of the atmosphere? (2 point)
Since the oceanic carbon reservoir is approx. 40 times larger than the atmospheric reservoir, small changes in the oceanic reservoir can severely affect the atmosphere.

b) How can photosynthetic feedback affect atmospheric CO_2 concentrations? (2 points)
Plants can increase the rate of photosynthesis and create more biomass, therefore removing CO_2 from the atmosphere.

c) What are the effects of weathering on atmospheric CO_2 concentrations? (2 points)
Silicate weathering removes CO_2 from the atmosphere. Carbonate weathering returns CO_2 to the atmosphere.

Oceanic Carbon-Sinks and Sources

a) How can oceans act as sinks or sources of CO_2? (3 points)
Primary producers in the surface layers of the oceans remove CO_2 from the water, allowing CO_2 from the atmosphere to diffuse into the water column. A large part of the biomass sinks to the bottom of the ocean, where it is decomposed (back to CO_2), but removed from the atmosphere (for a few 100 years).

b) Where in the oceans are major sources of CO_2? (2 points)
Upwelling zones, where CO_2 - rich water comes back to the surface.

c) Why are major regions of the oceans neither sources or sinks? (2 points)
They are rather unproductive due to the lack of nutrients.

d) How could you change that? (2 points)
Fertilize the oceans and increase primary productivity, e.g. by supplying Fe.

Long-term Carbon Storage

What are long-term reservoirs of Carbon? How do they get recycled? (2 points)
Carbonate rocks, plate tectonic processes.

Early Sun

a) What is the Faint Young Sun Paradox? (3 points)
Early in its history the sun was a very faint star, supplying approx. 30% less solar energy to the Earth. Nevertheless the earth's climate was warm enough for water to exist in its liquid state and allow life to develop.

b) Which solutions to the faint-young sun paradox have been suggested? (3 point)
additional heat sources (e.g. geothermal heat)
changes in albedo

better insulating atmosphere (increased greenhouse effect)

Age of the Earth (2 points)
According to geologists, what is our best estimate of the age of the Earth?

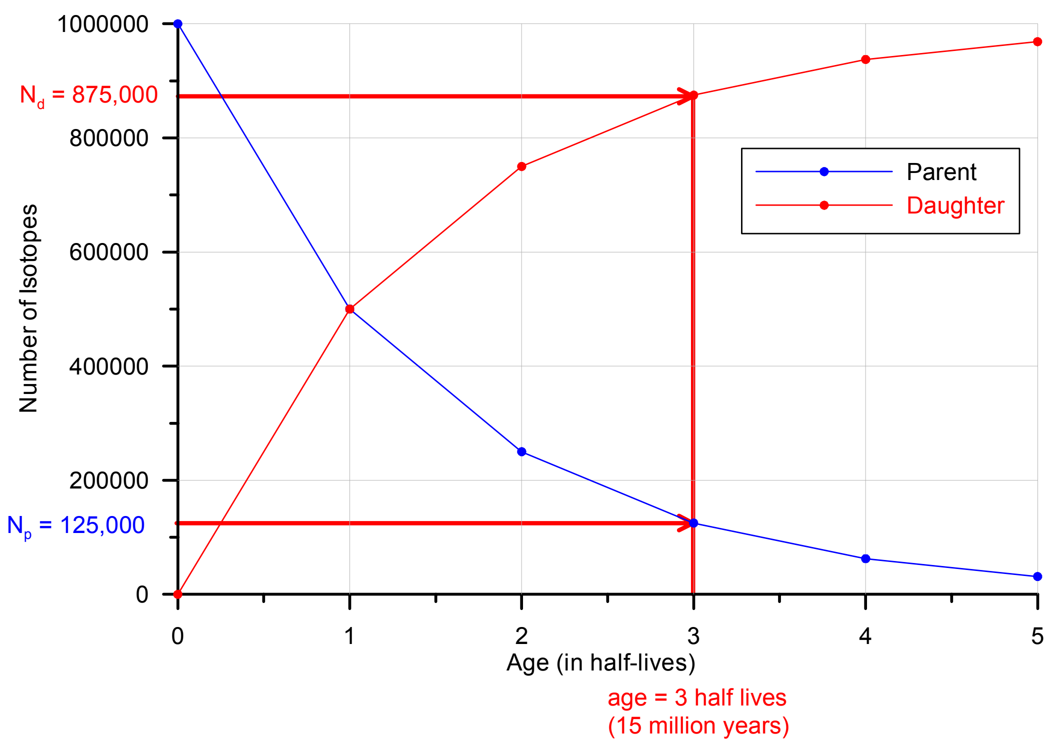
4.6 billion years

Dating of Geological Specimen

a) Starting with an initial number of parent isotopes N_0 = 1000000 **neatly and accurately** draw the decay curve of the parent isotope from t = 0 to t = 5 half lives. Use the sheet of graph paper provided. (3 points)

b) On the same graph add the growth curve of the daughter isotope. (3 points)

c) A rock sample has been analyzed for a certain radioactive isotope **A** and its daughter **B**. The analysis gave the following results: N_A = 125,000 isotopes, N_B = 875,000 isotopes. Assuming a half-life of $T_{1/2} = 5 \times 10^6$ years, no losses of either isotope except through radioactive decay and an initial concentration of daughter isotopes $N_{B0} = 0$. Calculate the age of the rock specimen. (4 points)



Yes, you can make your life difficult by using the numerical relationship between daughter and parent isotopes, which will yield approximately the same result.

Earthquake Zones
Why are most earthquakes located along fairly narrow zones? (2 points)

Because they occur where the edges of lithospheric plates interact with each other.