

ATOC 182 – Introduction to Oceanic Sciences Final Exam Study Guide

The final exam April 26 will pose problems and questions similar but not necessarily identical to the questions in this study guide. Each essay should cover a maximum of one side of a page of an exam booklet, with diagrams (if necessary) occupying the opposite page. Some answers will require much less space than this. You will have three hours to complete the exam, with my intention that the average time to completion will be about 2 hours than this.

The main goal of the exam is to encourage you to pull together the broad themes of the course and apply the problem-solving skills that I hope you will carry away with you for many years to come.

Note that any of the problems will use different numbers on the exam than those on this study guide.

Problems (remember to show all your work for each problem):

(1) Assume a three-step food chain (diatoms to copepods to small fish). If the transfer efficiency is 12% (0.12) between the diatoms and copepods and 8% (0.08) between the copepods and small fish

- (a) What is the transfer efficiency between diatoms and small fish?
- (b) If the diatoms are fixing carbon by photosynthesis at a rate of 0.40 grams carbon/m² per day, estimate the total primary productivity over an area of 20.0 km by 30.0 km for an entire year.
- (c) Estimate the grams of carbon incorporated into the small fish at the top of this three-step food chain.
- (d) Assuming the rate of production of fish holds exactly steady year after year at the rate found in (c), how many grams of fish could be removed from this system each year while maintaining a steady state for fish. Explain why the assumption of constant fish production is a dangerous one.

(2) During the Cold War, a US ship is searching for a Soviet submarine. It sends an acoustic signal downward into the ocean, which bounces off the submarine and returns to the ship 0.15 seconds later.

- a. At what depth is the submarine, assuming a constant speed of sound of 1450.0 m/s?
- b. Where should the Soviets try hiding the submarine to avoid detection: the sound speed minimum (the SOFAR channel) or the sound speed maximum. Justify your answer.

(3) Assume that the net heat transfer to the high latitudes of the North Atlantic due to the ocean's Meridional Overturning Circulation is approximately equal to:

$$Q = mc\Delta T$$

where Q is the heat transported in MOC per unit time, m is the mass transported in the overturning transport, c is the specific heat of water (3985 J/kg°C), and ΔT is the difference in temperature between the warm and cold waters.

- a. Given an overturning transport (m in the equation above) of 18.0×10^9 kg/s, average warm water temperatures of 20.0°C, and average cold water temperatures of 3.5°C, what is the northward heat transport in watts (where 1 watt = 1 J/s)?
- b. If this northward heat transport warms a region of the atmosphere that is 1.5×10^{14} m², what is the radiative forcing (i.e. the energy flux to the atmosphere in watts/m²) of the overturning circulation in this region?

(4) Using a one-box chemical balance model of the ocean and the following data, calculate the residence time of silicate in the ocean. First **draw** a diagram of the one-box model and then **solve** for the residence time. Assume steady state. The following are the data you may need:

$$C_{\text{river}} = 195.0 \text{ mmol/m}^3$$

$$C_{\text{ocean}} = 94.0 \text{ mmol/m}^3$$

$$R = 0.045 \times 10^6 \text{ km}^3/\text{year}$$

$$V_{\text{ocean}} = 1292 \times 10^6 \text{ km}^3$$

Here C_{river} is the concentration of silicate in the river, C_{ocean} is the concentration of silicate in the ocean, R is the rate of river inflow, and V_{ocean} is the volume of the ocean.

(5) If the West Antarctic Ice Sheet were to collapse, how much would global average sea level rise? Assume the density of the melt water is 1000 kg m⁻³, the mass of the West Antarctic Ice Sheet is 2.54×10^{18} kg, and the surface area of the world's oceans is 5×10^{14} m².

Short essay. (Be thorough but feel free to use concise “bullet-points.”)

Biological Productivity

(6) Describe the four phytoplankton we discussed in class: Cyanobacteria, Diatoms, Dinoflagellates, and Coccolithophorids.

(7) Describe the vertical and horizontal distribution of phytoplankton in the ocean and the causes of these distributions.

(8) Describe the process of photosynthesis, including its chemical formula.

(9) Multicellular organisms have long been known to use Programmed Cell Death to eliminate unwanted tissues. What hypotheses have been offered as to why unicellular organisms, such as phytoplankton, engage in such activity?

(10) Much of the Southern Ocean has high surface concentrations of the nutrients phosphate and nitrate, yet low biological productivity. Describe the theory that explains this apparent mystery and the experiments by which oceanographers tested this theory.

Humans and the Surface Ocean

(11) Explain how ocean warming and sea level rise can lead to “coral bleaching.” Include in your explanation a description of the phenomenon of coral bleaching.

(12) What is eutrophication, how is it caused, and what are two of its harmful consequences?

(13) Explain why fish of higher trophic levels contain higher concentrations of some contaminants in their tissues than fish of lower trophic levels.

(14) In the last fifty years, the world’s marine fish catch has grown from 40 million metric tons to more than 80 million metric tons. This has occurred at the same time that the most of the world fisheries have become either fully exploited or overexploited. How can you explain this seemingly contradictory situation?

Deep Ocean Circulation

(15) Name two chemical constituents found in seawater that are used as tracers of ocean circulation. Describe how they are useful for understanding the pathways of the overturning circulation.

(16) Describe how oceanographers use floats to understand the pathways of deep ocean circulation.

(17) What determines the density of sea water?

(18) Describe the intermediate, deep, and bottom water types of the ocean, where they form, and why they form there.

(19) The Westerly Winds and Polar Easterlies lead to both upwelling and downwelling in the Southern Ocean that forces an important component of the ocean's Meridional Overturning Circulation. Draw a cross-section of the region. Include the winds, the Ekman transport, and the upwelling and downwelling ocean currents. Label the water masses involved.

Deep Ocean Ecosystems

(20) Autotrophic chemosynthetic bacteria at hydrothermal vents fix carbon (i.e. they convert CO₂ to sugars). What provides the energy for this autotrophic process?

(21) Heterotrophs at the sea floor have two methods of securing food. Describe each method.

(22) What is diel vertical migration? What is the explanation for this behavior?

Sediments and Paleoceanography

(23) How are sediment cores used to reconstruct ancient climates?

(24) Where are the thickest marine sediments and why are they found there?

(25) Explain the difference between a hothouse climate and an interglacial.

Biogeochemistry

(26) Explain why chemicals in the ocean have such a wide range of residence times.

(27) Why is the ocean salty and the Great Lakes fresh?

(28) How does warming influence the ocean's storage of carbon?

The Oceans and Global Change

(29) What is a greenhouse gas? What are the principle greenhouse gases on our planet?

(30) What is ocean acidification and why are some people concerned about it?

(31) Why is sea level expected to rise in a warmer planet?

(32) What are 2 reasons local sea level change can differ from global average sea level change? Draw a diagram to help you explain each effect.