SIO 210 Introduction to Physical Oceanography
Mid-term Examination, Fall, 2004
ANSWER KEY (except for Hendershott questions)

October 26, 2004
11 – 12:20 AM
This is a closed book exam - no notes, no books.

2 long questions (25 points each)
2 short answer questions (10 points each),
6 True-False questions (5 points each).
Total: 100 points.
Points will be given for correct answers only (and deducted for incorrect or missing answers).

-------**Long answer questions**----------

1. Explain briefly why each of the following assertions is incorrect. The correct answers are very short, so pls think before you write and then don't include extraneous material.

(a) Ocean currents veer to the right in the northern hemisphere because the Coriolis Force acts to the right of the direction of motion in the northern hemisphere.

(b) The molecular viscosity of seawater is about 0.01 cm2/sec. On account of this, the waves generated by for example a tsunami should reverberate throughout the ocean for hundreds of days before finally being damped out by friction.

(c) The two accompanying figures show the predicted tide at San Diego for January 2004 and for April 2004. Explain, in one sentence, why the January tide is so much more diurnal than the April tide (hint: remember that the winter solstice is about 4 January).

2. Consider the potential temperature section from Antarctica (left) to Iceland (right):

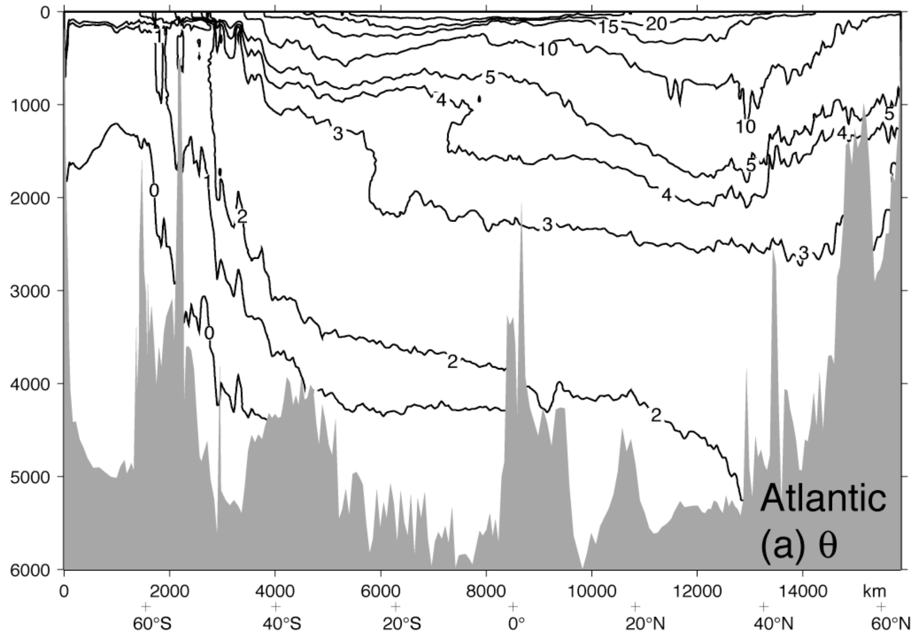

Fig. 1. Potential temperature from the Antarctic to Iceland. The Arctic is not shown.

(a) On Figure 1, indicate generally where the 2°C *temperature* isotherm would occur. you should have drawn it slightly below the 2°C potential temperature contour since the temperature at the 2°C potential temperature contour is higher than 2°C.

(b) On Figure 1, where would you expect major eastward geostrophic flow at about 2500 dbar to occur? You should have indicated general locations where the isotherms slope steeply. There is one region between 2000 and 4000 km, and another at the northernmost end of the section.

(c) In regard to your answer to (b), what does the temperature field actually tell you about the geostrophic velocity field? The temperature field probably looks a lot like potential temperature, which resembles the potential density field. With a section of potential density, you can calculate the vertical shear in the geostrophic velocity at every location. (If you have some other source of information about the geostrophic velocity at one depth at each horizontal location, you can then calculate the geostrophic velocity at all depths.)

Suppose you wish to trace two separate parcels of water, one from the surface layer in the Antarctic and one from the surface layer in the Arctic. Both of the parcels are dense enough to sink to great depth once they leave their source regions. Assume that the water parcels from the Arctic enter the North Atlantic at a potential temperature of 2.5°C. Assume that the water parcels from the Antarctic enter the deep ocean at a potential temperature of 0°C.

(d) In Figure 2a AND b, mark these two parcels IF they have the SAME initial potential density relative to the sea surface. You should have located 0°C and 2.5°C on the vertical axis of both figures. Then, since I didn't give you a salinity or potential density, just guess at one in the top plot, and make sure that both parcels are on the same density contour (with one at 0°C and the other at 2.5°C). Then place the exact same theta/S values on the lower panel, and you'll see that they don't have the same pot. dens. rel. to 4000 dbar.

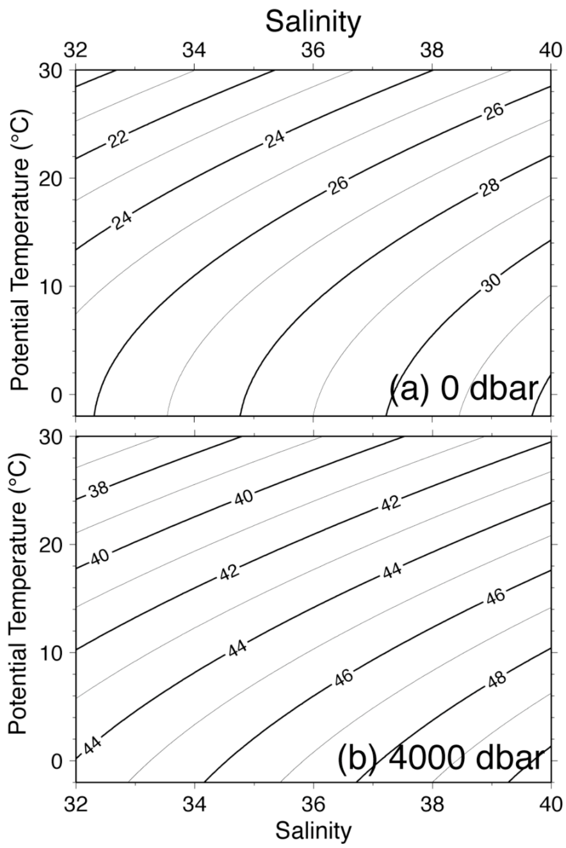

Fig. 2. Contours of potential density as a function of two different reference pressures.

(e) Once the water parcels enter the ocean and sink to depth (3000 to 4000 dbar), would they be found at the same depth or different depths? different

If the latter, which would be closer to the ocean bottom? The colder one will have a higher potential density relative to 4000 dbar (looking at the contour labels in the lower panel), and so it will be closer to the bottom.

(f) Mark on Figure 1 where the deep waters would be relatively fresh and relatively salty, assuming that there is little mixing, and assuming that the Antarctic and Arctic waters start at the same density relative to the sea surface. First identify the 0°C waters in the south, and assume these are the Antarctic waters. Then identify the 2.5°C waters in the north and assume these are the Arctic waters. If they start at the same potential density when they enter the Atlantic, then the 0°C water must be fresher than the 2.5°C water. So mark the general region of the 0°C isotherm in the S. Atlantic as "FRESH" and the general region of the 2.5°C isotherm in the N. Atlantic as "SALTY".

(g) Why is the overall slope of the isopycnal (constant density) contours in Fig. 2b different from the overall slope in Fig. 2a? (ignore the curvature of the contours) In your answer, explain what physical property of seawater leads to this result. The contours in 2b are flatter than in 2a (slope less steeply). This is because cold water is more compressible than warm, and so when waters of the same potential density relative to the sea surface are moved to 4000 dbar, the colder one becomes denser than the warmer one. This requires the contours in 2b to be flatter than in 2a.

(h) Now consider mixing processes in terms of Fig. 2a. Mixing occurs along straight lines in the potential temperature/salinity plane.
MARK at straight line between two parcels of water that have the same potential density, in Fig. 2a. Just pick two points that are pretty far apart along a single contour in 2a, and connect with a straight line.

Is the product of mixing these two parcels DENSER or LIGHTER than the original two parcels? (circle correct answer). (This effect is called *cabbelling*.) Now look at the density you have in the middle of the straight line. Because of the curvature of the isopycnal contours, the density in the middle of the line is GREATER than along the isopycnal.

-------**Short answer questions**----------

3. The accompanying figure is a prediction of tides at Eastport, Maine for one month. The tics at the bottom of the plot mark days of the month 1, 2, 3... . Choose the most nearly correct answer(s) to the following questions from this list of days:

6 14 18 24

Note, you will have to carefully count days at the bottom of the plot as the tics are not labelled. Note also that in some cases more than one answer may be correct.

A time of spring tides is most nearly
a. b. c. d.

A time of neap tides is most nearly
a. b. c. d.

A time of the moon's greatest angular distance out of the earth's equatorial plane is most nearly
a. b. c. d.

A time of lunar perigee is most nearly
a. b. c. d.

A time when the moon is in the earth's equatorial plane
is most nearly
a. b. c. d.

4. The Pacific Ocean is approximately 10,000 km wide and approximately 5,000 m deep. Consider a west-to-east cross-section across the whole width of the Pacific, from Japan to California. Assume that there is a narrow western boundary current and a very broad interior flow across most of the section.

(a) If the water in that cross-section is moving southward at 1 cm/sec, calculate the total southward volume transport, in MKS units. (Ignore the western boundary current for this calculation.) Volume transport is width x height x speed. Multiplying and keeping track of units, this is

(10000 x1e3) x (5000) x 0.01 = 5 x 1e8 m3/sec = 500 Sv.

(This is far too large for any ocean - that's because I told you the current goes to the bottom. A real circulation of about this speed would go just to about 1500 m.)

(b) If this same amount of water is returning northward in a western boundary current that is 100 km wide (and still 5 km deep), calculate the average northward velocity of the western boundary current. You can do this just by multiplying the interior speed of 1 cm/sec by 10000km/100km = 100, yielding a current speed of 100 cm/sec or 1 m/sec.

(c) If the average oxygen content of the northward flow in the western boundary current is 150 µmol/kg, calculate the net northward flux of oxygen in the western boundary current, in units of µmol/sec. Use the information from (b) to calculate.

The oxygen transport is the product: oxygen content x water density x volume transport.
(150 µmol/kg) x (1025 kg/m3) x (500 x 1e6 m3/sec) = 7.7 x1e13 µmol/sec

-------**True-false questions**----------

Please circle the appropriate response.
<u>If the answer is FALSE, explain why or give an answer that would make the statement true</u>.

5. Here is a list of kinds of waves

a. light (in vacuo)
b. long gravity (tsunami)
c. capillary
d. short gravity (swell)
e. acoustic (in ocean)
f. seismic (in solid earth)

and a list of typical wave speeds

cm/sec	_____
10-20 m/s	_____
200 m/s	_____
1500 m/s	_____
4-8 km/s	_____
3 10^8 m/s	_____

Beside each member of the speed list, write the letter indicating the type of wave whose speed most closely corresponds to that speed.

The accompanying section for (6) and (7) is for sigma_0 (you can consider it to be for density by the relationship density=1+sigma_0/1000 so that, for example, sigma_0=27.5 corresponds to a density of 1.0275 gm/cm3). The vertical axis is depth (m) and the horizontal axis is north-south distance in km (0 to 13000) from the southernmost part of the plot. Answer the following questions regarding the component of geostrophic flow normal to the plane of the figure by circling correct answer a, b, c...

6. At the horizontal location labeled 1000 km (about 54 deg S), the flow at 500 m depth is

a. eastward with respect to the flow at 1500 m depth,
b. westward with respect to the flow at 1500 m depth,
c. same speed and direction as the flow at 1500 m depth.

7. At the horizontal location labeled 2500 km (about 41 deg S), the absolute value of the difference between the flow at 500 m depth and that at 1500 m is

a. greater than the corresponding difference at the horizontal location 1000 km,
b. less than the corresponding difference at the horizontal location 1000 km,
c. same as than the corresponding difference at the horizontal location 1000 km,

(no question 8)

9. Oceanographers like to quantify the amount of water or chemicals moving with a current.
(a) A volume transport of 10 Sv (1 Sverdrup = 1 x 10^6 m^3/sec) includes about the same amount of seawater as a mass transport of 1 x 10^{10} kg/sec. TRUE or FALSE

10. The following properties of seawater depend on temperature, pressure and/or salinity.
(a) Sound speed increases with decreasing temperature. TRUE or FALSE
Here I was thinking about the physical process that governs sound speed (sound speed increases with increasing temperature and with increasing pressure). However, if you were thinking about an actual temperature and sound speed profile in say the North Pacific, then in the deeper waters, sound speed increases while temperature decreases. So this wasn't a very good question.

(b) The temperature of the maximum density of water decreases with increasing salinity. TRUE or FALSE

(c) The freezing point of water increases with increasing salinity. TRUE or FALSE

(d) Sea ice floats because the seawater under it is all at about 4°C. TRUE or FALSE

(e) The compressibility of seawater increases with decreasing temperature. TRUE or FALSE