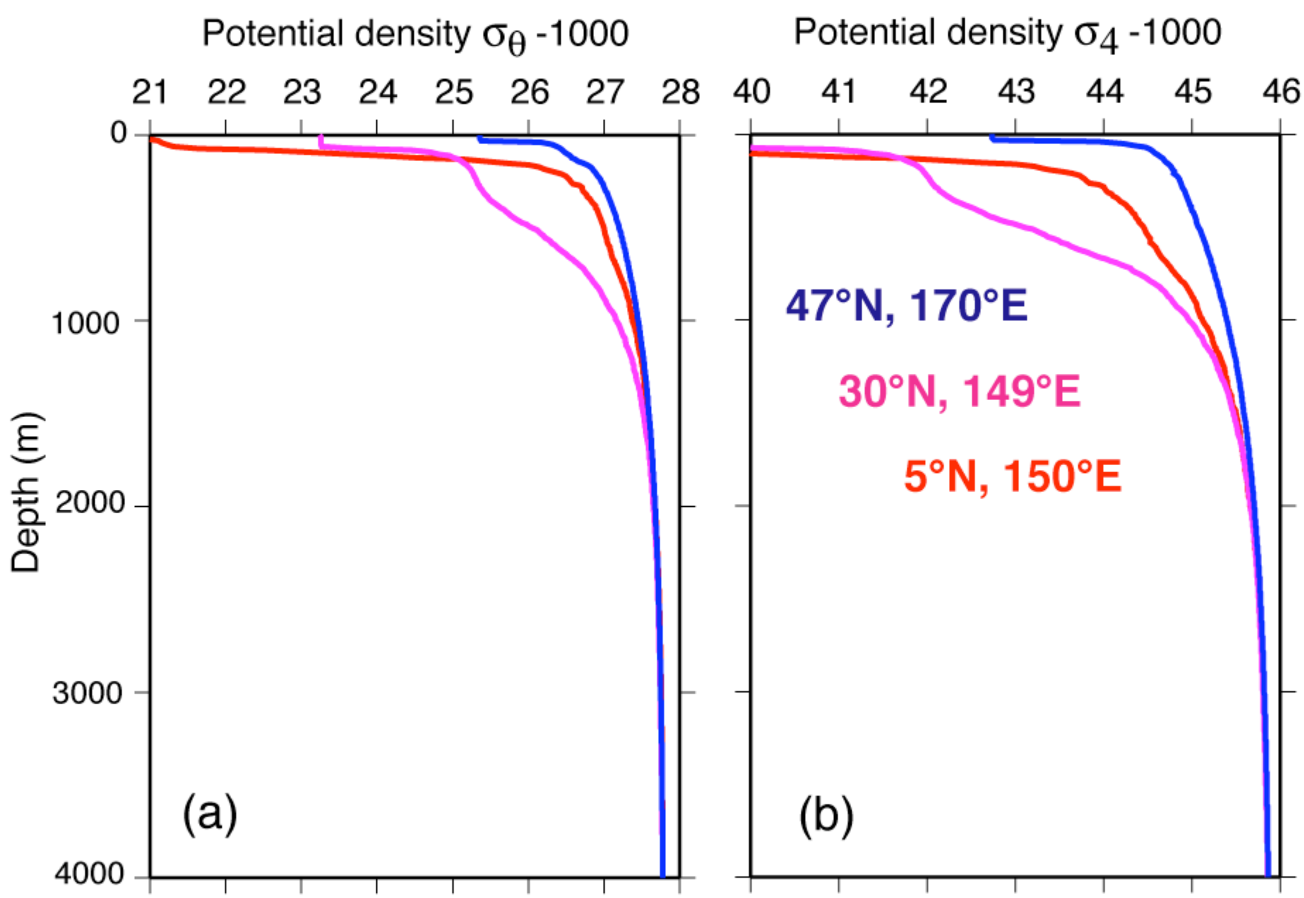
SIO 210 Introduction to Physical Oceanography
Mid-term examination
Monday, October 30, 2006
2:00 – 2:50 PM

This is a closed book exam. Calculators are allowed but might not be necessary. (100 total points.)

1. The figure shows two types of potential density at locations in the North Pacific. The same stations are used on both plots.
(a) Define potential density. What are its units?

Potential density is the density a parcel has when moved adiabatically to a reference pressure. (A common reference pressure is the sea surface.)
Its units are kg/m^3

(questions continued after figure)



(Problem 1 continued)

(b) What is the difference between the way that one calculates the potential density plotted in the left panel and the potential density plotted in the right panel? In the left panel, it is calculated relative to the sea surface. In the right panel, it is calculated relative to 4000 dbar.

(c) Explain the different sizes of the values in the two panels. (Why are they different and why are values in the right panel larger than in the left?)
Values in the right panel are larger because density itself is larger at 4000 dbar than at the sea surface, simply due to compression of the water parcel.

(d) Look at the difference in the two potential densities between the purple and blue profiles at about 200 meters depth. Which is larger? Explain.
This question was a bit poorly worded.
On the left panel, the density difference between purple and blue is about 1.8 kg/m^3.
On the right panel, the density difference is about 3 kg/m^3.
The blue curves are of water that is colder than the purple curves. Cold water is more compressible than warm water. When the parcels are moved (in theory) to 4000 dbar, the cold parcel will compress more, and the density difference between the parcels will increase compared with the density difference near the sea surface.
Many people answered this using the contours of potential density in theta-S space, which was a fine way to do it.

Define and then locate an example on the figure:

(e) mixed layer: Surface layer of uniform density. Two very small mixed layers on the left panel – very thin layers compared with winter mixed layers that we talked about in class.

(f) pycnocline: layer where density changes rapidly. There is at least one pycnocline on each profile.

(g) pycnostad: layer where density changes slowly, embedded in the pycnocline and somewhat close to the sea surface. There is a pycnostad on the purple curve, at about 300 m depth.

2. The Rossby number is a non-dimensional parameter that is associated with the importance of rotation.

Using this simplified equation of motion for one of the horizontal directions:

acceleration + Coriolis = forces (2.1)

$\partial u/\partial t - fv =$ forces (2.2)

where $f = 2\,\Omega \sin(\text{latitude})$ and $\Omega = 0.73 \times 10^{-4}$ sec^{-1}
Assume that latitude = 30° so that sin(latitude) = 0.5.

The Rossby number allows us to compare the sizes of the two terms on the left-hand side with each other.

In order to compare these two terms, you have to choose a velocity scale and a time scale. Assume that the velocity scales for u and v (in the two horizontal directions) are the same.

(a) In symbols only, what is the ratio of the size of the acceleration term to the Coriolis term? (Use 2.2) (This is the Rossby number. As a check on your work, it should have no units).

Choose a velocity scale of U and a time scale of T. (You can also say that the time scale is $T = L/U$ where L is a space scale.)

Therefore the size of the acceleration term is U/T (or U^2/L).

The size of the Coriolis term is fU, since U is a generic scale that applies to both u and v, and since f is just a parameter (it just has a given value).

Therefore the ratio is Rossby number = $(U/T) / fU = 1/fT$
[or Rossby number = $(U^2/L) / fU = U/fL$]

Choose reasonable velocity and time scales for the following and calculate an approximate Rossby number:

First, the size of $f = 1\text{x}10^{-4}$ /sec.

(b) surface wave

If U = 1 m/s and L = 1 m (or T = 1 s), the Rossby number = 10^4

(c) Gulf Stream

If U = 1 m/s and L = 10^5 m (or T = 10^5 s ~ 10 days), the Rossby number = 10^{-1}

(d) Atmosphere's storms

If U = 10 m/s and L = 10^6 m (or T = 10^4 s ~ 1 day), the Rossby number = 10^{-1}

3. Water flows into and out of a box, shown in the figure.

(a) What are the units of the total *mass* transport INTO the box? kg/sec

(b) If the average velocity of the water into that side of the box is 5 cm/sec, calculate the mass transport using the dimensions shown in the figure and a reasonable single value for density.

$T = \rho v A$

$\rho \sim 1000$ kg/m^3

v = 5 cm/sec = 0.05 m/sec

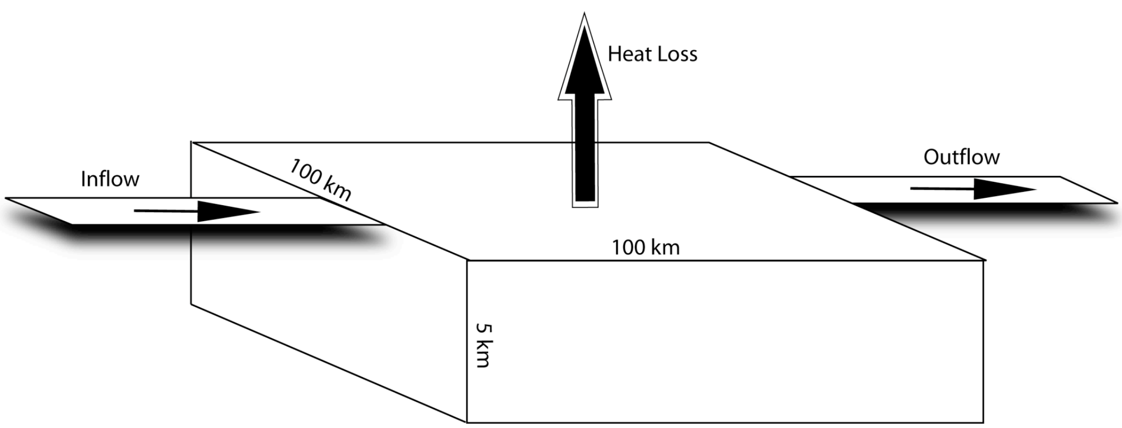
100 km * 5 km *106 m^2/km^2

so T ~ 2.5 x 10^{10} kg/sec

(c) If you know the mass transport into the box, what can you say about the mass transport out of the box? equal (to within the very small correction for any net evaporation or precipitation)

(d) If the arrow at the top represents evaporation – precipitation, and the direction of the arrow means that there is net evaporation, is the salinity of the outflow larger or smaller than the salinity of the inflow? (no calculation)

larger



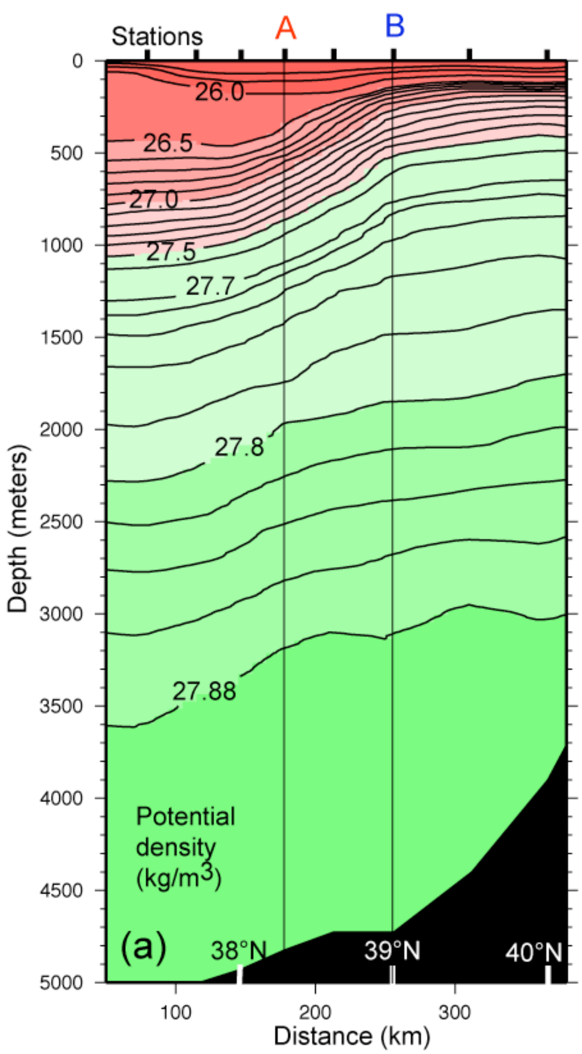
4. The left figure is potential density relative to the sea surface at a location in the North Atlantic.

(a) Indicate on the figure where you expect to find the strongest current (in both the distance and depth coordinates).

Just to the right of "A", between the surface and about 400 m depth

(b) Sketch the most likely distribution of sea surface height just above the section. Can't do this in the doc file - draw the mirror image of, say, the 26.5 isopycnal

(questions continued below the figure)



(Problem 4 continued)

(c) Indicate on the figure the most likely direction of the current between A and B at 1000 m depth.   Out of the page

(d) What is the relative strength of the current at 1000 m compared with the strongest current you indicated for (a)?   (SHORT ANSWER – please do not calculate anything and don't explain – see part f below) ___weaker___

(e) In the blank panel to the right, sketch the vertical profiles of potential density at both A and B. can't do this on the doc file. These are continuous curves with depth as the vertical axis and potential density as the horizontal axis. "A" is lower then "B" in the upper ocean and asymptotes to "B" with depth.

(f) Use the difference in density between A and B to explain the answer to (d). The sea surface at A is higher than at B, which drives the strongest flow out of the page. Because density at A is lower than at B, at least in the upper water column, the total mass between the sea surface and 1000 m at A is somewhat reduced compared with what it would be if the density structure at A were exactly like that at B. Therefore the pgf at 1000 m is smaller than at the sea surface.

SIO 210 Fall 2006, Final questions on waves and tides. (Hendershott)

There are all multiple choice questions, please answer by circling the letter next to the most nearly correct answer or writing the correct letter in the blank space provided.

TIDES. (i), (ii) easy; (iii), (iv) novel

(i) At most open ocean ports the time interval from one high tide to the very next high tide is most nearly

a. 12 hours,
b. 12 hours 25 minutes,
c. 11 hours 35 minutes,
d. 24 hours,
e. 24 hours 25 minutes,
e. 23 hours 35 minutes.

(ii) At ports where the tide is nearly entirely diurnal, the tidal range nearly vanishes

a. at new or full moon,
b. at the quarter moons,
c. when the moon passes through the earth's equatorial plane,
d. when the moon is farthest out of the earth's equatorial plane.

(iii) If the earth rotated clockwise viewed from above the north pole rather than counterclockwise (the true sense of rotation), then at most open ocean ports the time interval from one high tide to the very next high tide would be most nearly

a. 12 hours,
b. 12 hours 25 minutes,
c. 11 hours 35 minutes,
d. 24 hours,
e. 24 hours 25 minutes,
f. 23 hours 35 minutes.

(iv) Suppose that that the sun did not generate tides, and that the moon and its elliptical orbit about the earth were in the earth's equatorial plane, and that the earth rotated on its axis once per month, so that the moon always appeared at the same place in the sky. Then the dominant interval between adjacent high tides would be about

a. 1/2 day, b. one day,
c. two weeks, d. one month,
e. one year.

WAVES. (i), (ii) easy, (iii), (iv) more difficult

(i) Match the kind of wave,

a. capillary waves, b. long swell, c. tsunami in open ocean,
d. sound in water, e. seismic waves in solid earth,

to the following wave speed list

few tens of m/sec	___b___,
1500 m/sec	___d___,
few kilometers/s	___e___,
200 m/sec	___c___,
few cm/sec to few tens of cm/sec	___a___.

(ii) The fact that deep water surface gravity waves generated by large storms are dispersive (long waves go faster than short ones) means that at a port distant from a storm, the period of waves arriving from the storm

a. increases, b. decreases, c. does not change

with the passage of time after the storm increases.

(iii) The speed of propagation of ocean surface gravity waves would decrease if gravity

a. increased, b. decreased,

It would also decrease if the density of the water were

a. increased, b. decreased

to a value only somewhat larger than the density of air (hint: don't rely on the wave speed formulas from class, they assumed there was no air. Rather remember that an ocean surface gravity wave is really an internal wave between the two fluids air and water, ask yourself how the speed of an internal wave would change if the density difference between layers were decreased.)

(iv) The phenomenon of refraction is important both in gravity waves that enter shallow water on the way to the beach and in sound waves that travel vertically in the ocean. In the ocean, sound waves originating at the depth of the sound speed minimum (the SOFAR channel) are generally refracted

a. back towards the center of the SOFAR channel,
b. up or down away from the center of the SOFAR channel.

Consider gravity waves that enter shallow water on the way to the beach. They are refracted as they pass over variable bottom relief. Which feature of bottom relief is analogous to the SOFAR channel in the tendency of refraction to direct gravity waves relative to the center of the relief feature in the same sense that refraction directs sound waves relative to the center of the SOFAR channel?

a. a submarine canyon
b. a submarine ridge (the opposite of a canyon).