

SIO 210 Introduction to Physical Oceanography  
Mid-term examination  
October 31, 2011; 50 minutes

Closed book. A calculator is allowed.  
(100 total points.)

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**Possibly useful expressions and values**

$$1 \text{ Sv} = 1 \times 10^6 \text{ m}^3/\text{sec}$$

$$g = 9.8 \text{ m/s}^2$$

$$\rho = 1025 \text{ kg/m}^3$$

$$c_p = 4000 \text{ J/kg}^\circ\text{C}$$

$$F \sim \rho V(S_o - S_i)/S_m$$

$$f = 2\Omega \sin(\text{latitude})$$

$$\Omega = 0.71 \times 10^{-4}/\text{sec}$$

acceleration + advection + Coriolis force = pressure gradient force + gravity + friction

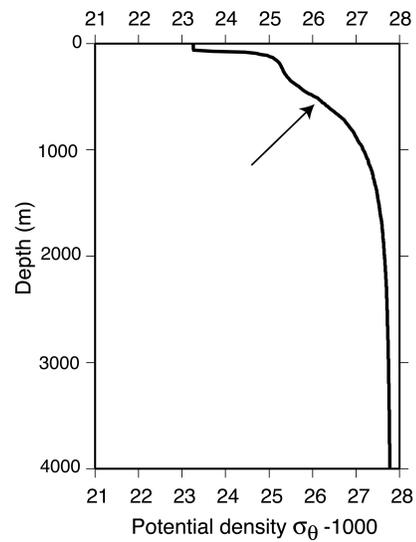
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**Multiple choice** (5 problems, 4 points each, 20 points total)

For each problem, **circle the CORRECT answer**. (There should be only one.)

1. In the vertical profile of density shown in the figure, the arrow points to the

- (a) Thermocline
- (b) Mode water
- (c) Abyssal ocean
- (d) Pycnocline



2. Which of these makes Lagrangian observations?

- (a) Subsurface float in the Argo program
- (b) Satellite ocean color sensor
- (c) Moored current meter at the equator
- (d) Research ship making CTD observations every 100 km along a straight track from California to Asia

3. Which of these equations expresses hydrostatic balance?

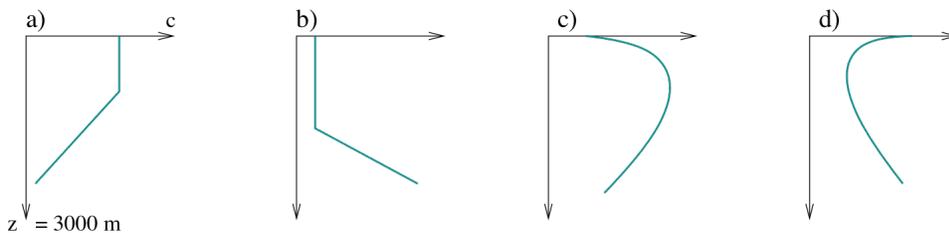
(a)  $D\rho/Dt + \rho(\partial u/\partial x + \partial v/\partial y + \partial w/\partial z) = 0$

(b)  $0 = -(1/\rho)\partial p/\partial z - g$

(c)  $N^2 = -g (\partial\rho/\partial z)/\rho_0$

(d)  $Dw/Dt = -(1/\rho)\partial p/\partial z - g + \partial/\partial x(A_H\partial w/\partial x) + \partial/\partial y(A_H\partial w/\partial y) + \partial/\partial z(A_V\partial w/\partial z)$

4. Which of the following is a typical profile of sound speed in the mid-latitude ocean?



5. In the Mediterranean Sea there is excess evaporation and cooling of waters that flow in from the Atlantic Ocean through the Strait of Gibraltar. These waters then return to the Atlantic Ocean. Flow through the strait is **NOT** characterized by the following

(a) Potential density of the outflow is greater than the potential density of the inflow

(b) Salinity of the inflow is greater than the salinity of the outflow.

(c) Mass transport into the Mediterranean is greater than the mass transport out of the Mediterranean

**Short answer** (2 problems, 20 points each, 40 points total)

6. Two water parcels (call them “A” and “B”) have the same density at the sea surface. Parcel “A” has a *lower* salinity than parcel “B”.

(a) At the sea surface, is the temperature of “A” **HIGHER** or **LOWER** than the temperature of “B”? (circle the correct answer)

(b) Is the potential density  $\sigma_\theta$  of “A” **HIGHER**, **LOWER**, or **EQUAL** to the potential density  $\sigma_\theta$  of “B”? (circle the correct answer).

Explain your answer: \_\_\_\_\_

(c) Is the potential density referenced to 4000 dbar of “A” **HIGHER, LOWER, or EQUAL** to the potential density reference to 4000 dbar of “B”? (circle the correct answer).

Explain your answer: \_\_\_\_\_

7. Of the following terms, state which pair forms the primary balance for each of the following approximations.

Terms:

- Pressure Gradient Force
- Temporal change in velocity (acceleration)
- Coriolis “force”
- Gravity
- Tidal Potential
- Centrifugal Force

(a) Hydrostatic Balance: \_\_\_\_\_ and \_\_\_\_\_

(b) Surface Waves: \_\_\_\_\_ and \_\_\_\_\_

(c) Inertial Oscillations: \_\_\_\_\_ and \_\_\_\_\_

(d) Geostrophic balance: \_\_\_\_\_ and \_\_\_\_\_

**Longer problem** (1 problem: 40 points total)

8. Geostrophic flow, transport, net heat transport, throw in names, scaling

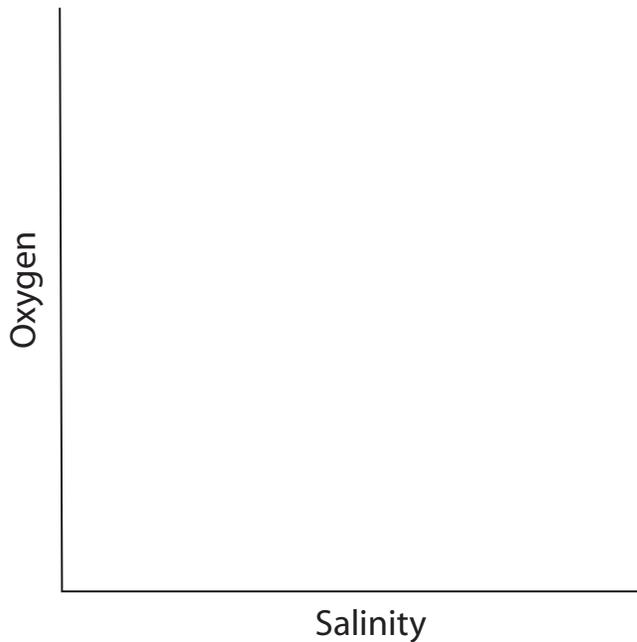
(SEE COLOR FIGURES AT BACK OF EXAM.)

The attached meridional sections are from the Pacific Ocean, at about 150°W. Their location is shown on the small inset map.

Label them as salinity and oxygen correctly.

(a) Indicate on the sections the location of the Shallow Salinity Maximum Water (also known as Subtropical Underwater). What external forcing (outside of the ocean) creates the high salinity in these maxima?

(b) Contrast the two regions: around 5°S and around 25°N. On the attached axes, sketch the oxygen vs. salinity relation in these two regions.



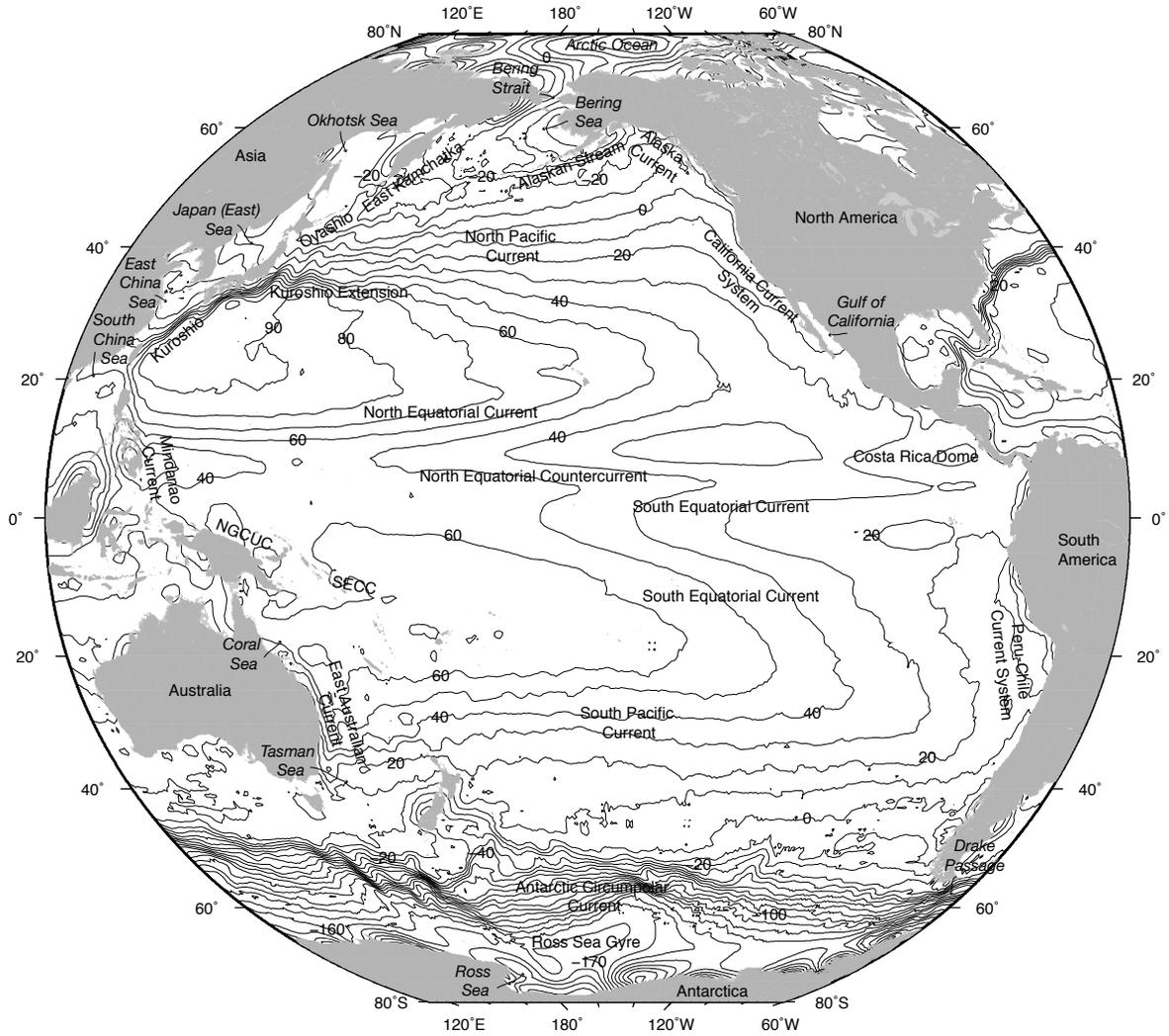
(c) What is the physical process that creates these salinity maxima within the ocean? If you don't know the answer precisely, then what physical process is responsible for creating the stratification in this overall layer of the ocean?

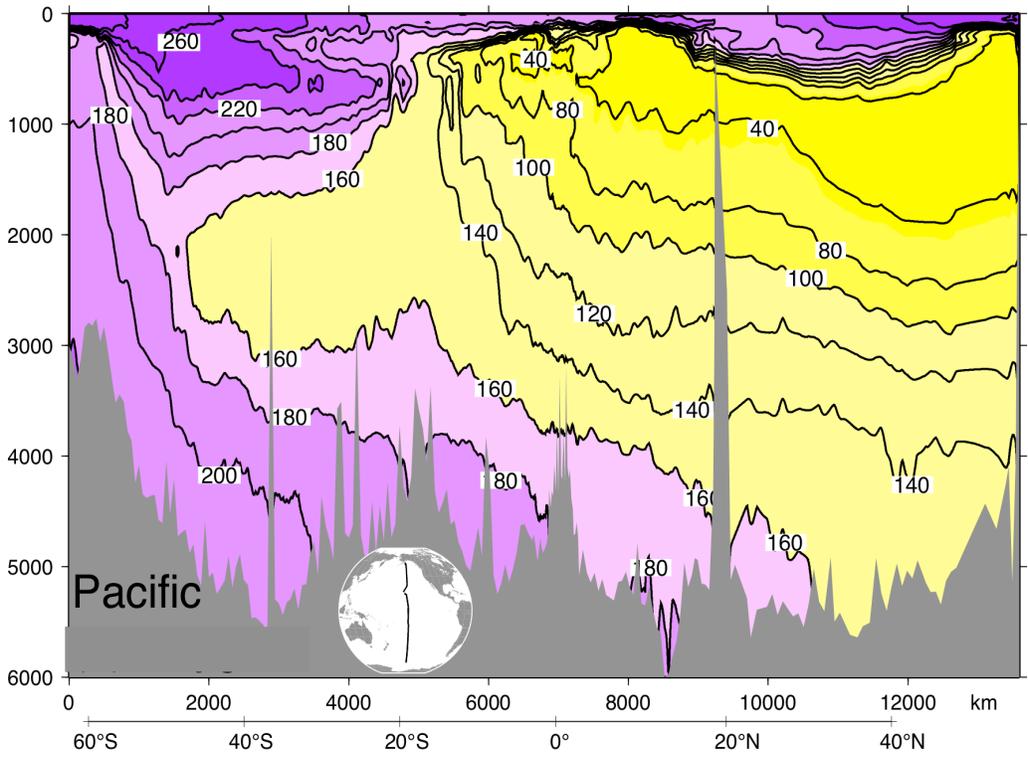
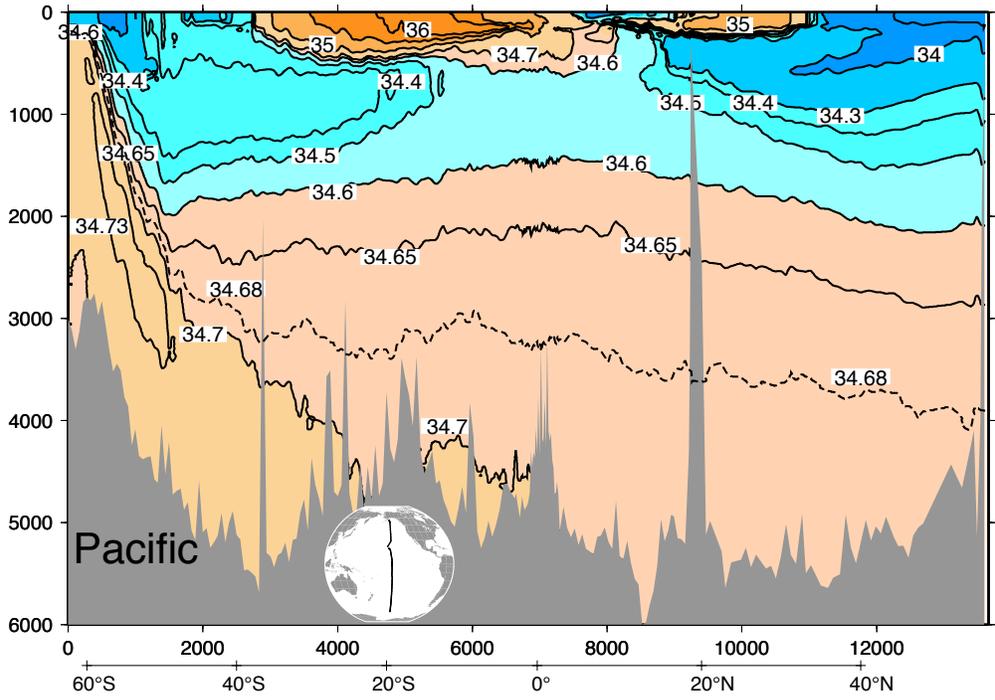
(d) Why is the water column vertically stable in the presence of subsurface salinity maxima?

(e) Suppose that the source water for the Salinity Maximum in the North Pacific is 34.5 psu and that the salinity shown on the meridional section is representative of the entire Salinity Maximum layer. If the total formation rate of this water mass is 4 Sv, calculate the net freshwater **transport flux** across the sea surface, in Sverdrups.

(f) The attached map shows the surface steric height (dynamic height) of the Pacific Ocean. Indicate on the map the region of the Salinity Maximum water in the North Pacific from the previous parts of the question.

Indicate the direction of flow in the gyre where this water mass is found. (Assume that the circulation is geostrophic.)





(For problem 8)