ANSWER KEY #1

SIO 210 Introduction to Physical Oceanography — LYNNE TALLEY
Mid-term Examination, Fall, 2002

October 24,2002
11:10 AM - 12:30

This is a 1-hour and 20-minute closed book exam - no notes, no books. You may use a calculator.

The final grade will be an average of this mid-term and the final.

----

(15) 1. Give a typical height H and horizontal length scale L, and then the non-dimensional aspect ratio for the following: $\delta = H/L$

3 (a) surface wave — $H \sim 1$ m, $L \sim 1$ m to 10 m — $\delta = H/L = O(1)$

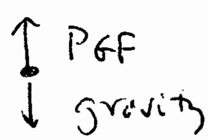
3 (b) Atlantic Ocean circulation — $H \sim 1$ km - 5 km, $L \sim 5000$ km — $\delta = H/L = O(10^{-3})$

3 (c) mesoscale eddy (for instance, a Gulf Stream or Kuroshio ring)

$H \sim 1$ km
$L \sim 100$ km — $\delta = H/L = O(10^{-2})$

2 2. What are the forces that balance in hydrostatic balance? gravity and pressure gradient force (vertical component)

Sketch the force vectors in this balance.

2 

3. Diffusivity κ has units of $(\text{length})^2$ / time.

(a) Describe very briefly (1-2 sentences) what we mean by "eddy diffusivity".

2 "Diffusivity" due to stirring/mixing by turbulent motions at a smaller scale than the scale one is studying. Examples of processes that contribute to eddy diffusivity: breaking internal waves, stirring by mesoscale eddies

(10)

(b) The molecular diffusivity of temperature in water is 0.0014 cm^2 /sec. Approximately how long would it take for temperature to diffuse 50 meters? (You may round the diffusivity to 0.001.)

4

$K = 0.0014 \, cm^2/sec$

$[K] = \frac{L^2}{T} \quad T = \frac{L^2}{K} = \frac{(50 \times 100 cm)^2}{1.4 \times 10^{-3} cm^2/sec} = 1.8 \times 10^{10} sec$

(c) Is eddy diffusivity larger or smaller than molecular diffusivity? larger

1

(d) Approximately how large is vertical eddy diffusivity? (a general order of magnitude is fine - you don't need to remember the exact numbers in class) 1 cm^2/sec to 0.1 cm^2/sec

1

(e) Approximately how long would it take for temperature to diffuse 50 meters if it diffuses through eddy diffusivity?

4

$T = \frac{(50 \times 100 cm)^2}{1 cm^2/sec} = 2.5 \times 10^7 sec$

5)

4. The potential temperature/salinity diagram here has two dots on it. One (the cold, fresh one) is the property of water flowing into the North Atlantic from the Nordic Seas, on the sill just east of Greenland. The second (warm, salty) is the water flowing into the North Atlantic from the Mediterranean, on the sill at the Strait of Gibraltar.

1

(a) What is the potential density relative to the sea surface σ_θ of these two water parcels? 28.0

2

(b) There is a difference between the measured temperature and potential temperature. Is the *measured* temperature of the two parcels

HIGHER (WARMER) or **LOWER (COLDER)**

than the potential temperature? (circle one)

2

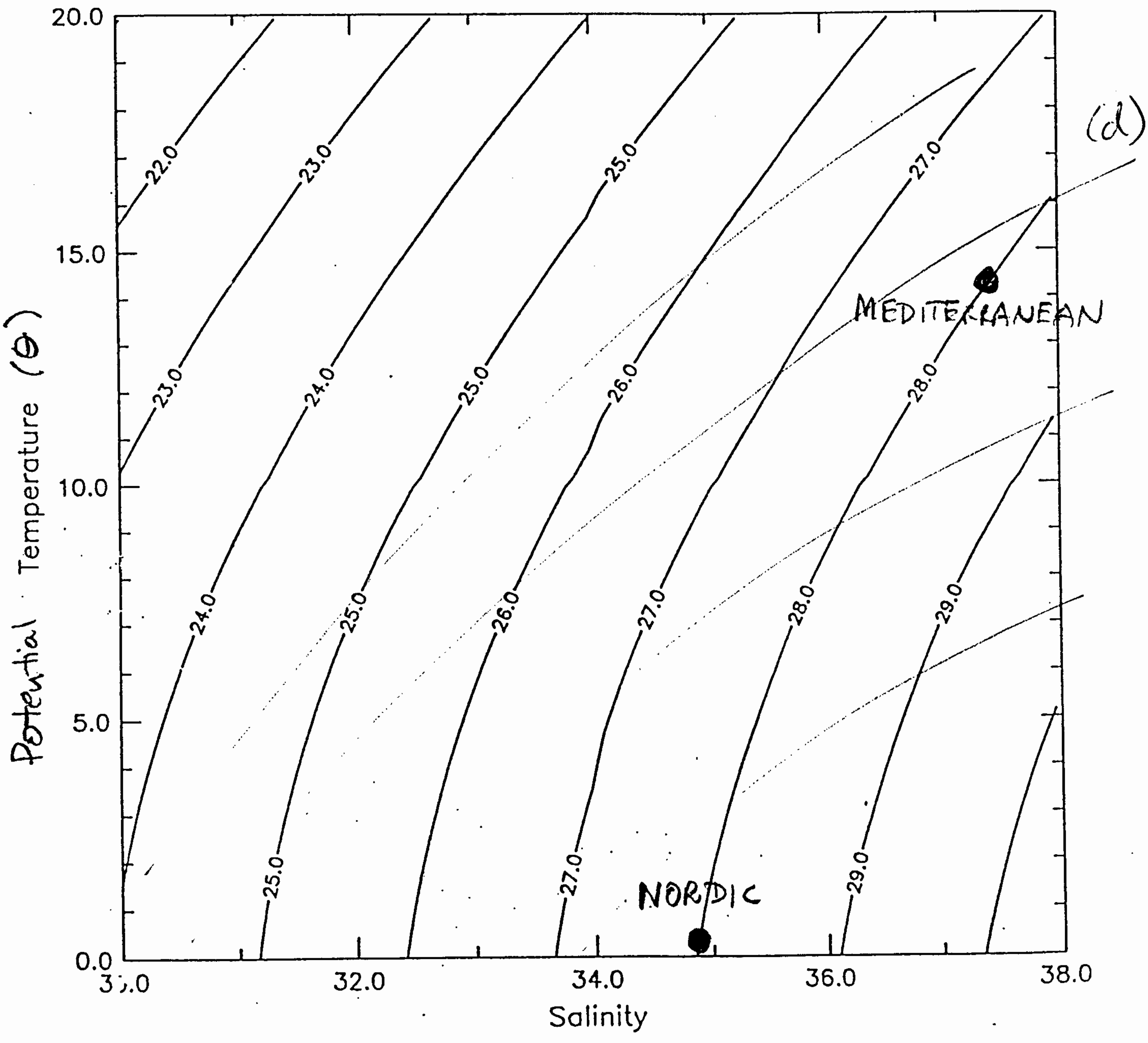
(c) Which parcel has a larger difference between the measured temperature and potential temperature? **NORDIC SEAS** or **MEDITERRANEAN SEA** (circle one).

(d) On the diagram, sketch in the contours of potential density σ_3 relative to 3000 dbar (that is, relative to a pressure higher than the sea surface pressure). This does not need to be exact, but please get the relative slope/angle of the contours.

2

(e) Relative to 3000 dbar, is the potential density of the Mediterranean parcel **HIGHER** or **LOWER** than the potential density of the Nordic Seas parcel? (circle one)

2



σ_θ [redacted]tential density 0 dbar

(18)

5. The attached figure (next page) is a potential temperature section from south to north through the length of the Atlantic Ocean. For most of the questions, assume that potential density (or neutral density) is similar in shape to potential temperature

2 (a) On the figure: Circle the Antarctic Circumpolar Current.

2 (b) On the figure: Draw a force vector for the pressure gradient force at the Antarctic Circumpolar Current.

2 (c) On the figure: Draw a force vector for the Coriolis force at the Antarctic Circumpolar Current.

2 (d) On the figure: Sketch the slope of the sea surface at the Antarctic Circumpolar Current.

2 (e) On the figure: Indicate through some means which direction the Antarctic Circumpolar Current is flowing (words, arrows, etc).

4 (f) If the Antarctic Circumpolar Current velocities average 5 cm/sec over the full depth of the ocean, estimate the volume transport of the ACC. (Estimate dimensions of the current from the figure.)

$V = 5$ cm/sec $= .05$ m/sec

$H = 5000$ m

$W_{ideal} \cong 10°$ latitude ~ 1000 km $= 10^6$ m

Transport $= VHW$

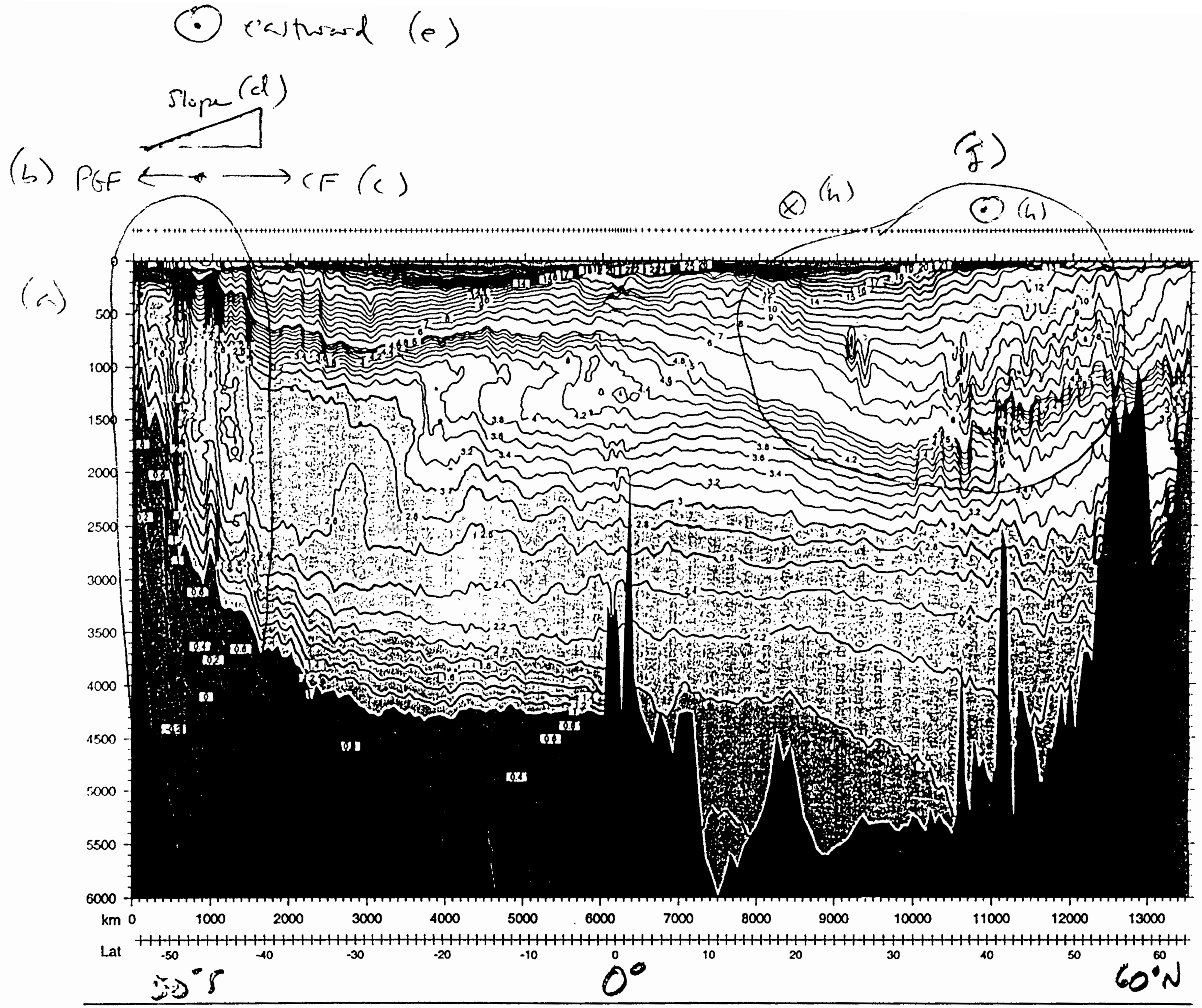
$= (.05 \frac{m}{sec})(5000m)(10^6 m)$

$= 250 \times 10^6 m^3/sec$

(actual is $\sim 100 \times 10^6 m^3/sec$)

2 (g) Circle the region of the North Atlantic's *subtropical* wind-driven circulation, recalling that this figure is a long distance from either the western or eastern boundaries.

2 (h) As in (d) [corrected to (e)], indicate the direction of general flow in the North Atlantic wind-driven subtropical gyre.



eastward (e)
Slope (d)
(b) PGF
CF (c)
(a)
(h)
(f)
(h)
km
Lat
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000
-50 -40 -30 -20 -10 0 10 20 30 40 50 60
0°
60°N

6. The attached figure is nitrate (a nutrient) at the sea surface in the Pacific Ocean. There are some regions of high and low nutrients.

(12)

(a) Explain very briefly why nutrients are very low in the subtropical surface waters.

2

Ekman pumping creates downwelling. Nutrients are constantly being used in the upper layer (euphotic zone) ~100 m thick. The downwelling does not allow replenishment of nutrients from below.

(b) Indicate the *non-tropical* regions where the large-scale flow (throughout the ocean and not at the boundaries) is likely to be poleward (northwards in the northern hemisphere, southward in the southern hemisphere).

2

(c) Explain very briefly how you arrived at your answer to (b).

2

High nutrients implies upwelling, which is due to Ekman suction. Sverdrup balance in these regions results in poleward flow.

(d) On the map, draw the general region of westerly winds in the North Pacific.

2

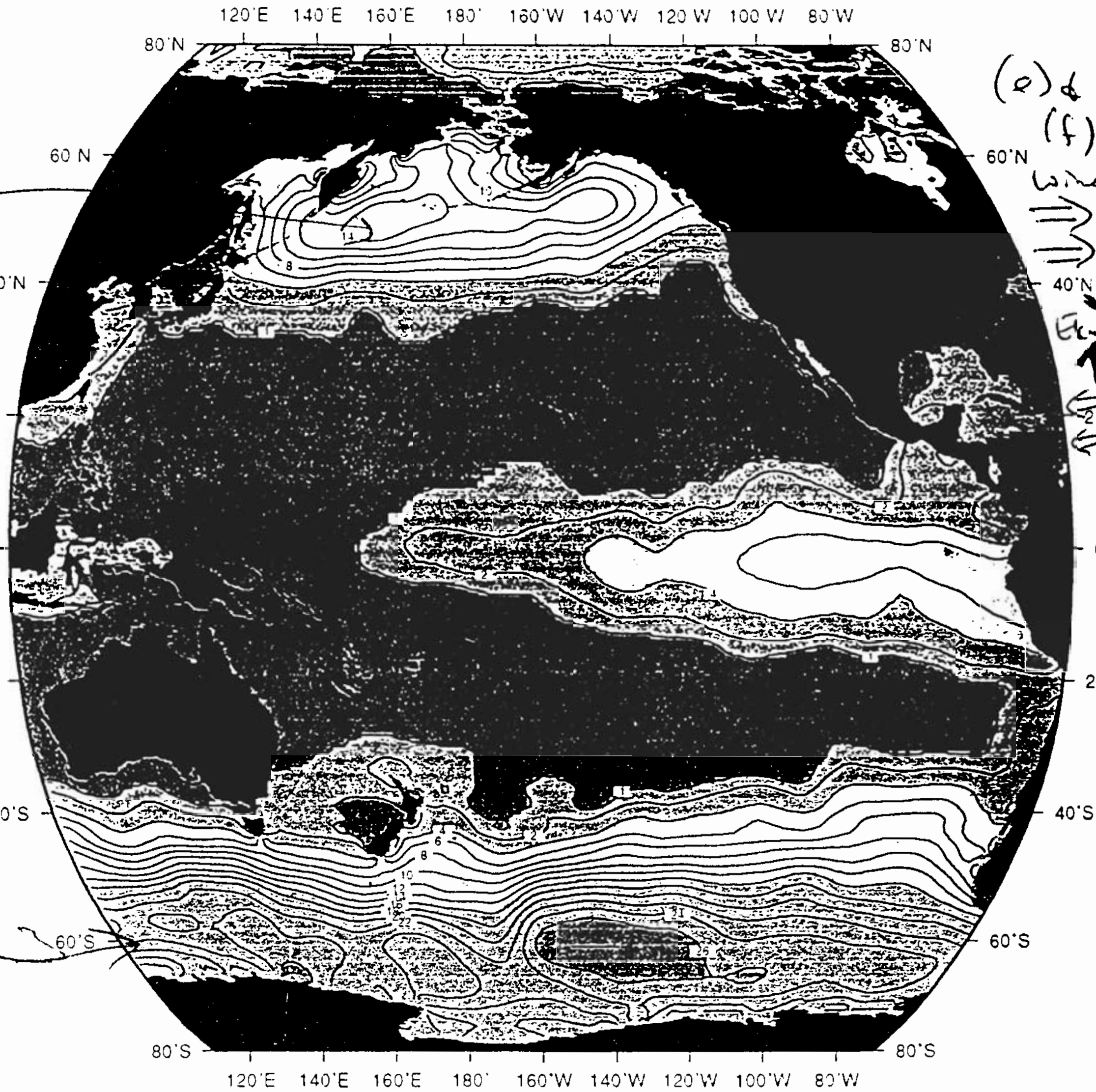
(e) On the map, draw the general region of trade winds in the North Pacific.

2

(f) On the map, sketch the direction of Ekman transport associated with these winds.

2

Annual mean nitrate 10m (Levitus)



(b) poleward

(d) westerlies

(e) trades

(b) poleward

(e) & (f) wind

Ekman