1. (a) Suppose you wish to measure ocean mesoscale variability, what types of autonomous instruments that were described in class might be useful? Choose a parameter that it might measure (could be physical or biological or chemical – temperature, salinity, chlorophyll, sound, alkalinity, etc.).

(b) To design an experiment to measure mesoscale variability with this instrument, answer the following to work out an optimal sampling rate and deployment time for this instrument. Be sure to phrase your answers in units of observations per time (e.g. hour/day/week/year).

   (i) What is the time scale of mesoscale variability?

   (ii) How long would you need to measure to characterize mesoscale variability with a good degree of confidence?

   (iii) How frequently would you need to measure to characterize mesoscale variability?

(c) What would be an appropriate sampling rate if the goal were to observe internal wave variability? What kinds of instruments would be appropriate?

2. Suppose the temperature of upwelled water at the coast of California is 10°C and the temperature of water offshore to the west is 20°C. Suppose there is a distance of 100 km between these two extrema.

(a) If there is a westward flow at 10 cm/sec, what is the temperature change over one week at a point between these two extremes? (Suppose that the temperature gradient between these two points is linear so that it can be approximated by the difference in temperature over the distance of 100 km.) Write down the terms in the temperature equation (or heat equation) that you use to solve this.

(b) If, instead, this is a steady state with no eddy diffusion, with the coast always cold and the offshore region always warm, and westward offshore flow, and a linear temperature gradient, then what is the heating rate at the sea surface that is required to maintain the steady state? Write down the terms in the temperature (or heat equation) that you use to solve this.
(c) Suppose the lateral eddy field can act as a horizontal eddy diffusion that mixes the cold and warm surface waters laterally. Typical horizontal eddy diffusivities are 1000 m$^2$/sec. Suppose that there is a steady state, with no surface air-sea fluxes (no surface heating), then what must be true about the structure of the temperature field between the warm offshore and cold onshore water? (Hint: write down the terms in the temperature equation that would express this balance.)

3. Consider the flow in a perfectly circular mesoscale eddy out in the middle of the ocean. Suppose it is 200 km in diameter, and that the sea surface in the middle of the eddy is 20 cm higher than on the outside of the eddy.

(a) Assuming a typical seawater density and a value for g, and that the water column is uniform density of 1025 kg/m$^3$, what is the difference in pressure between the center of the eddy and outside the eddy? Write down the correct momentum balance that gives you this answer, and then calculate the pressure difference.

(b) If the Earth is NOT rotating, calculate the horizontal acceleration caused by this pressure difference from the inside of the eddy to the outside of the eddy. (Draw a schematic to make it clear what you are calculating.)

(c) If the Earth is rotating, and this eddy is at 30°N, draw a schematic of the eddy looking down from the top, and of the flow field in the eddy. Ignoring the fact that this is a circular eddy, calculate the velocity associated with the horizontal pressure gradient force at this latitude.

4. (a) The molecular diffusivity of temperature in water is 0.0014 cm$^2$/sec. Approximately how long does it take for temperature to diffuse 50 meters? (use dimensional analysis for diffusivity – you have all you need right here in those 2 sentences.)

(b) The vertical eddy diffusivity is approximately 0.1 cm$^2$/sec. Answer the same question as in (a).

(c) What process(es) contribute to this vertical eddy diffusivity? (what is meant by the concept?)
5. (a) The plots show temperature and potential temperature profiles at two different locations in the North Pacific. On each plot, indicate which curve is temperature and which is potential temperature.

(b) On the plots above, indicate where the thermocline is found.

(c) On the plots above, indicate where there is a thermostad.

(d) Construct a very simple "vertical section" from these two profiles. That is, in the following box, make a vertical section of potential temperature.
(e) Assume that potential density contours look just like potential temperature contours. On the plot in (d) indicate the direction of geostrophic flow at the sea surface if it is zero at the bottom. (Please do not calculate anything.)

(f) Above the plot in (d), sketch the sea surface based on your result for (e).

(g) For your sketch for (f), indicate very roughly what the relative height of the sea surface is at one location compared with another. Assume that these stations are typical of the North Pacific's gyre. (I am not interested in an exact number, but I do want the order of magnitude to be correct in comparison with the isothermal depth variations.)

6. On the attached salinity section:
(a) Label the “4 layers” (schematically)

(b) Label the major water masses based on our class examples.

Choose 2 of the water masses from (b).
(c) How do you identify each of the two water masses you’ve chosen?

(d) What is the formation history of the two water masses you’ve chosen?

(e) What would a chlorofluorocarbon section look like along this longitude in the Atlantic? You can reason from basic principles, and from the oxygen section that is included in the textbook in Chapter 4. You may also go ahead and look for a
chlorofluorocarbon section for this longitude (they are out there, you just need to look), and describe its main features in terms of the water masses.