OCES 2003 Assignment 2, Spring 2021

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Set on: Tue 2nd Mar; due: Tue 9th Mar

Blurb

- Assignments have a maximum mark out of 20, although you will see that there are 22 marks available to get in total, i.e. if you get 22/20 you still only get credit for 20/20
  - 16-17 is roughly around the A- boundary
  - anything below 8 is probably a fail
  - there may or may not be bonus prizes for those who consistently try to get beyond the maximum mark, or you can use it to satisfy your own ego that you went above and beyond :)
- There will be at least one question that is 'hard' and/or 'open-ended'
- Please show working in calculation
  - no working + wrong answer = no credit whatsoever
  - some working + wrong answer = partial credit
  - generically, give things to 2 decimal place and provide the appropriate units (marks are allocated for these), unless otherwise specified
- No answers except the 'hard' ones should need more than a paragraph / half a page. Excess answers that are not to the point will be penalised.
- Type up the assignment or send a photo of your written up work in (the former is preferred). The only request I have is no Microsoft Word documents (you can type up things with Word but export it as a pdf if you do).
  - write in full sentences where appropriate
  - particularly poor and/or scrappy presentation will have a mark that can be taken off
- There will be a rigid mark scheme, and model solutions will be available in due course
  - the TAs only mark the stuff, you should come to the instructor for arguing marks, and note the re-marking can result in marks going up or down

Problems

1. Consider the linear equation of state given by

$$\rho = \rho_0[1 - \alpha(T - T_0) + \beta(S - S_0)].$$

   Taking the references as $\rho_0 = 1000$ kg m^{-3}, $T_0 = 25$ °C, and $S_0 = S = 36$ g kg^{-1}. Give the density associated with the following accurate to one decimal place in the sense of 1234.5 units:

   (a) $\alpha = 2 \times 10^{-4}$ °C^{-1}, $\beta = 2 \times 10^{-4}$ g^{-1} kg, $T = 26$ °C, $S = 36.5$ g kg^{-1}?

   (b) $\alpha = 2 \times 10^{-4}$ K^{-1}, $\beta = 2 \times 10^{-3}$ g^{-1} kg, $T = 26$ °C, $S = 36.5$ g kg^{-1}?

   (c) $\alpha = 1 \times 10^{-4}$ °C^{-1}, $\beta = 2 \times 10^{-4}$ g^{-1} kg, $T = 25$ °C, $S = 3.65$ mg g^{-1}? (1 mg = 10^{-3} g; the location of the decimal places are intended)

   (d) as part (*a*), but give your answer in units of pounds per cubic inch (lb inch^{-3}, use 1 kg = 2.2 lb and 1 inch = 2.5 cm) and accurate to one decimal place in the form of 1.2×10^3 units.

[4 marks]

2. What 'density' (in-situ, potential neutral, others) should we be thinking about for ρ above? Justify your answer.

[1 mark]

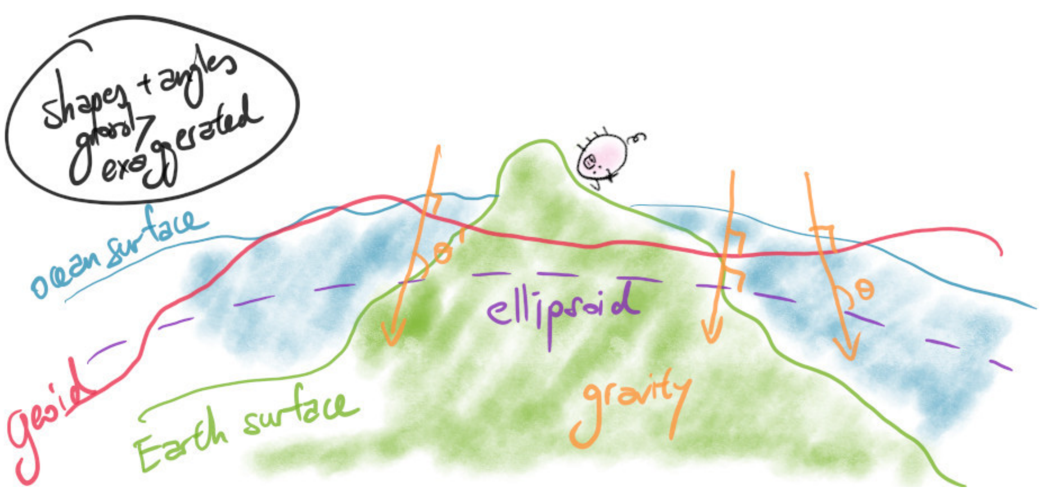
3. Explain in your own words why in-situ temperature increases as you go to the deeper parts of the ocean, and why it is usually an inappropriate variable as a measure of of whether the stratification is stable or unstable that is sufficiently deep.

[1 mark]

4. From Lec 7, we worked out that $g_{\mathrm{Earth}} = 10$ m s^{-2}. Use the same numbers in the lecture slides but compute instead g_{pig}, assuming that $m_{\mathrm{pig}} = 0.1$ metric tonnes, giving the answer accurate to one decimal place in the sense of 1.2×10^3. Why is it really small compared to g_{Earth}?

[1 mark]

5. Recall the following diagram from Lec 7:



Sketch on the SSH, assuming everything you see here are time means (you may or may not want to redraw this diagram yourself; inclusion of pig is optional). [1 mark]

6. State whether the following are cyclonic, anti-cyclonic, both, or neither (justify your answer):
   (a) the Ross gyre;
   (b) the Beaufort gyre;
   (c) an eddy with geostrophic upwelling in the Southern Hemisphere;
   (d) a pig doing a somersault (assume motion is only in a vertical plane);
   (e) hurricane Katrina;
   (f) Jupiter's Great Red Spot, which is an anti-clockwise vortex.

   [3 marks]

7. What is the Ekman pumping and/or suction associated with a uniform wind stress in the middle of an ocean away from land? Justify your answer.

   [1 mark]

8. There is this claim that "*if you flush a standard domestic toilet and it goes one way in the Northern Hemisphere, you flush the same toilet in the Southern Hemisphere the flow would go the other way because of the Coriolis effect*". Comment on the validity of this claim, and provide some quantitative evidence, i.e. back things up with a calculation (order of magnitude estimates are fine). Reference any sources you do use.

   [3 marks]

9. (More open ended) Suppose we have an indestructible toilet that can flush under any circumstance (Elon Musk is definitely working on this), would your answer to the above question change if you were on a *pulsar* instead (look this up)? Back up your claims by calculations and references as appropriate.

   [3 marks]

10. (More open ended) During *El-Niño events* the equatorial Pacific winds tend to reverse, from the usual westward winds to eastward winds. Within the context of Ekman dynamics, state any physical, chemical and/or biological consequences this can have for the equatorial *Pacific ocean* (stick to the consequences for the ocean rather than the atmosphere, although the atmosphere is important through the *Bjerknes feedback*). Justify your claims accordingly, and state any sources you do use.

    [4 marks]

!? (Harder) It turns out *potential* temperature θ is actually not a great thermodynamic variable to use. Look up *conservative* temperature (denoted Θ, capital theta) and write maybe a page or two (with appropriate referencing) on what is so bad about θ, and why Θ is a more sensible thing to use. The references on the Wikipedia page is a good place to start; the TEOS-10 webpage has some tutorial slides on the left hand bottom corner, which might be more accessible than the original paper of McDougall (2003).