OCES 2003 sort of finals, Spring 2022

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Set on: Thurs 26th May; due: Thurs 26th May

Blurb

- The final has a maximum mark out of 20, but there are 22 marks available
  - 17-18 is roughly around the A- boundary
  - anything below 10 is probably a fail
- 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, and 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), and 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

!!! By handing something in, you agree to the usual Academic Honour code and Integrity declarations. For more, see `http://qa.ust.hk/aos/academic_integrity.html`. Cases for plagiarism (whether intended or not, it is the "act" that matters) gets a penalty ranging from

  - zero on the question concerned
  - a fixed penalty starting from around 1/3 of the total marks
  - zero for the whole assignment
  - zero for the whole course
  - academic suspension, expulsion etc.

  The following counts as plagiarism (and is a non-exhaustive list):

  - copying from others and/or websites like Chegg; when found, both the copier and (where relevant) the person copied from will at a minimum get zero for the assessment (in line with university policy), with possibility for failing the whole course, and possibly with academic suspension (repeated cases will lead to expulsion)
  - copying word for word *any* (i.e. one or more) sentence without quote marks regardless of whether it is cited or not, e.g. *Yer a Jedi, Harry* (Gandalf of House Stark)
    * use quote marks if need be, e.g. "*Yer a Jedi, Harry*" (Gandalf of House Stark), although don't do it too often, because then one could argue you are not passing any of your thoughts through
    * any more than around three usages in text is probably excessive
  - copying without citation or wrong citation, e.g. "*Yer a Jedi, Harry*", or "*Yer a Jedi, Harry*" (Jon Snow of Tatooine)
  - changing a few words but sentence largely the same, e.g. *You, Harry, sir, are a Jedi* (Mithrandir of Winterfell)

- Turnitin will pick out most of the aforementioned things
- Cases can be contested but will lead to an official review, where the penalty may go up and/or down, and will most likely lead to an Academic Misconduct case being filed (see `https://acadreg.ust.hk/generalreg.html\#b`)
- You do not have to cite lecture materials from this course, unless you want to

Problems

1. **(6 marks)** Question about in-situ/potential density/temperature.

   (a) Explain in your own words what is "potential density/temperature referenced to the sea surface", and how that is different to in-situ density/temperature. [2 marks]

   (b) Give a brief description of the thermal wind shear relation, where your answer must include the words "density", "geostrophic flow" and "gradient". Which density in part (*a*) should we be thinking about here? Explain your answer. [2 marks]

   (c) The claim in the lectures is that "*from a dynamics point of view, it is almost never in-situ density/temperature we care about*". Give two ocean examples where if in-situ instead of potential density/temperature was used it would lead to scenarios that would be inconsistent with physical observations and/or dynamical expectations.

   [2 marks]

   (Hint: Use/reproduce some diagrams in the lecture notes to help you make your point if you like.)

2. **(6 marks)** Under projected climate change the winds over the Southern Ocean is projected to increase, in magnitude as well as in *gradients* (e.g. Marshall (2003), *Trends in the Southern Annular Mode from observations and reanalyses* in Journal of Climate).

   (a) Assuming eddy properties stay fixed, how might we expect the following to vary? Explain your answer (and be precise about it, e.g. increase/decrease in what, and because of what).

      i. Ekman up/downwelling in the Southern Ocean
      ii. residual overturning cell in the Southern Ocean
      iii. Southern Ocean pycnocline
      iv. Antarctic Circumpolar Current transport

   [4 marks]

   (b) Given the Southern Ocean and global ocean connectivity through the isopycnals, in the above scenario and assuming all else stays the same, how might we expect the following to vary? Explain your answer (and be precise about it, e.g. increase/decrease in what, and because of what).

      i. depth of the North Atlantic Deep Water extent (related to the Atlantic Meridional Overturning Circulation)
      ii. the global ocean heat content (proportional to the global integrated temperature)

   [2 marks]

   (Hint: You don't strictly need it, but the paper by Mak, Marshall, Madec & Maddison (2022), *Acute sensitivity of global ocean circulation and heat content to eddy energy dissipation time-scale* in Geophysical Research Letters may or may not be useful.)

3. **(6 marks)** An approximate version of the dispersion relation for internal waves in the ocean is given by

$$\omega = \pm\sqrt{f_0^2 + \frac{N^2 k_x^2}{k_z^2}}.$$

(a) Give a one or two (short-ish) sentence definition for ω, f_0, N, and $k_{x,z}$. [2 marks]

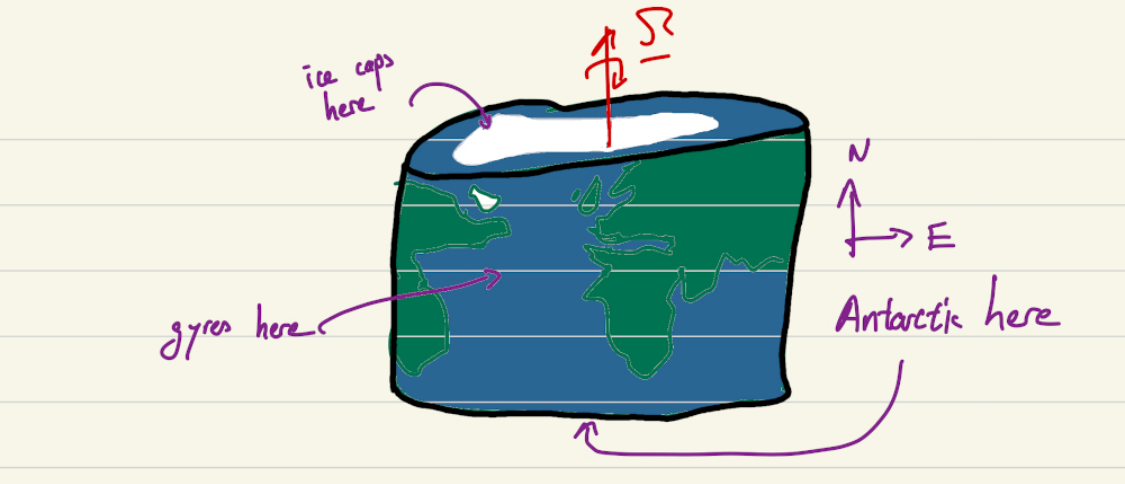
(b) Internal waves have the property that the phase velocity is perpendicular to the group velocity. Explain how phase and group velocities are different, and why the stated fact here tells us that internal waves are *dispersive* waves. [2 marks]

(c) For large k_x, is it internal waves or the analogous *surface* inertia-gravity waves

$$\omega = \pm\sqrt{f_0^2 + gHk_x^2}$$

that are expected to have a higher ω? What about for the horizontal phase speeds? Explain your answer via some numerical comparison (hint: try assignment 4 for some numbers you might want). [2 marks]

4. **(4 marks)** As you may know there are people in the world who believe the world is flat. Lets suppose there are also people who believe the world is cylindrical like the following (badly drawn) diagram:



Assuming we are actually dealing with a 'perfect' cylinder (unlike the wonky schematic I drew), that there are no changes to the geographical wind patterns whatsoever, and the ocean gyres of concern are not on the 'edges' of the cylinder. Describe the expected gyre circulations and western boundary intensification and state/explain differences you would expect (if any).

[4 marks]

(Hint: What is β here?)

(Note: It is entirely possible to get full marks in this question using one sensible sentence.)