OCES 2003 sort of finals, Spring 2024

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Set on: Sat 25th May; due: Sun 26th May

Blurb

- The final has a maximum mark out of 30, although there are a maximum of 40 marks available
  - yes the large number of marks available is deliberate, and we will mark everything you hand in, although you can get full marks not doing that
  - 24 is roughly around the A- boundary
  - anything below 14 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

!!! 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. **(8 marks)** Question relates to Coriolis effect and gyre circulation.

   (a) Suppose you have a disk Earth and cylinder Earth: Draw out a disk and a cylinder, and draw the rotation axis to be perpendicular to the disk and the non-curved side of the cylinder for the cylinder (have it pointing up for simplicity). Using your diagram, explain in no more than a sentence on why there is no planetary β for both of these cases.

   [2 marks]

   (b) Suppose your ocean and relevant land features are on the disk for the flat Earth, or the curved side on the cylinder Earth. Provide an analogous explanation (pictorial or otherwise) as in Lecture 11 and 12 on why there is no implied western intensification for both the flat Earth and cylinder Earth setting.

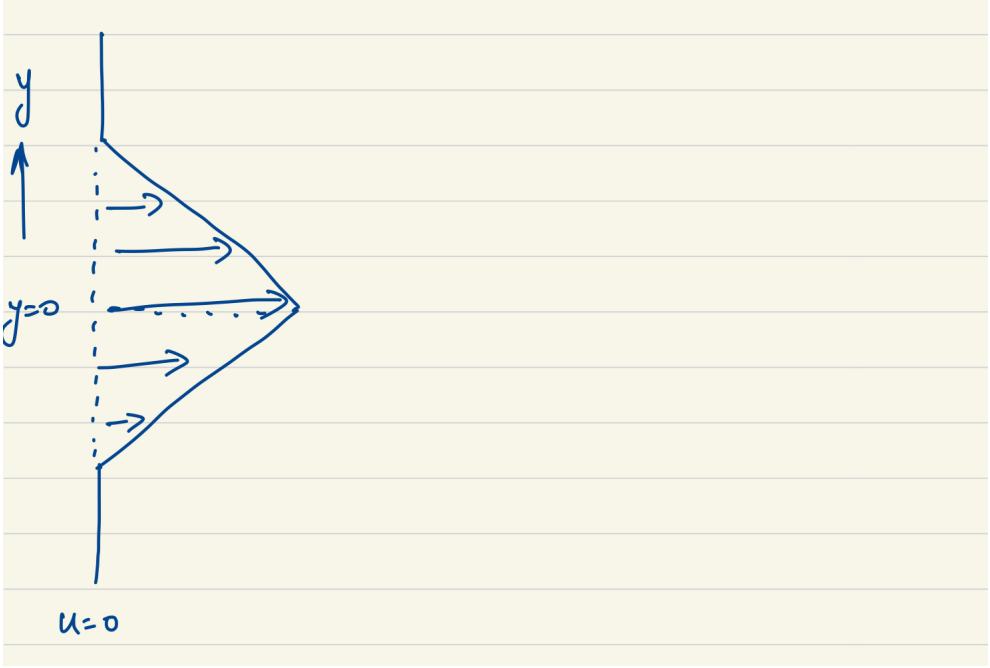
   [4 marks]

   (c) Explain (pictorial or otherwise) why there are no planetary Rossby waves in the flat Earth and cylinder Earth system.

   [2 marks]

2. **(14 marks)** Question relates to instabilities and vorticity waves.

   (a) Suppose we have the following velocity profile (you might want to make your a few copies of this):



   Draw on

   - the vorticity profile $Q = -\partial U/\partial y$ associated with the given velocity profile
   - the three edge waves on each of the "corners" of the given velocity profile such that they are all *in-phase*
   - their associated vorticity anomalies, and deduce their direction of propagation

   [6 marks]

(b) Make another copy of the diagram above, and draw on a *stable* configuration, where the three edge waves are appropriately phase-shifted such that there is destructive interference.

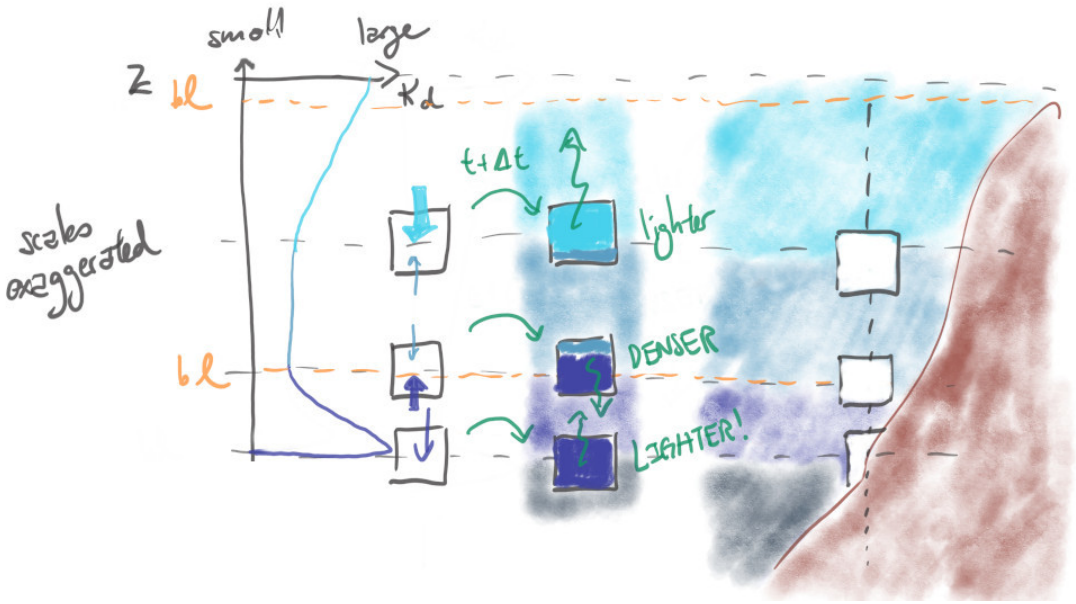
[4 marks]

(c) In one of the tutorial sessions we went through a case where gravity waves could be interpreted in terms of vorticity leading to self-induced advection, for a case with stable stratification with $N^2 > 0$. Draw a similar explanation out but for the $N^2 < 0$ case, i.e. a pictorial explanation for static instability, by doing the following:

- draw an indication of the background density or buoyancy (but indicate which variable you are using) corresponding to $N^2 < 0$ that is like the piecewise-constant vorticity profile in Q2*a*
- draw on a waveform at an interface
- argue what the implied vorticity anomalies should be at the *nodes* of the waveform
- then argue what the induced velocity centred at the nodes will do to the peaks and troughs of the waveform, demonstrating an increase in the amplitude and thus instability

[4 marks]

3. **(8 marks)** Recall from Lecture 14 there was this diagram about boundary intensified upwelling:



One consequence of this updated view of abyssal upwelling is that the magnitude of upwelling depends on the steepness of the bathymetry through the *in-crop* area, and also on the roughness of the bathymetry. Boundary intensified upwelling rate is larger for less steep bathymetry, and increased roughness of local bathymetry (e.g. de Lavergne et al, 2016, Journal of Physical Oceanography; de Lavergne et al., 2017, Nature).

(a) Provide a pictorial explanation analogous to the above diagram on why the upwelling rate might depend on the steepness of the bathymetry through the in-crop area. Explain your reasoning accordingly in your pictorial diagram.

[4 marks]

(b) Provide a pictorial schematic on why upwelling should increase with local roughness of the bathymetry. Explain your reasoning accordingly in your pictorial diagram (one sentence can be enough).

[4 marks]

(WARNING!!! If you copy figures from articles, cite them, or get penalised heavily for plagiarism.)

4. **(6 marks)** Question relates to tides. Suppose for no particularly good reason Elon Musk decides to and succeeds in splitting up the Earth's moon, such that the moon of mass M_{moon} splits into two smaller moons each of mass $M_{\text{moon}}/2$, and they end up orbiting the Earth exactly at the opposite end of each other. Draw out such a configuration, and explain why the equilibrium tides on Earth remain exactly the same.

   (Hint: After Lamb (1932). Redo what I did in the lectures but with two moons of equal but half the original mass, and assume we have linearity so that the effects of each moon are additive).

   [6 marks]

5. **(4 marks)** Question relates to equations of state. *Cabelling* is a process where mixing of two water masses *of the same density* can lead to the resulting watermass being denser than before, and is important for deep water formation.

   (a) Provide a pictorial argument as to why cabbelling cannot exist in a linear equation of state.

   [2 marks]

   (b) Sketch out a hypothetical case of a nonlinear equation of state where you can get reverse/anti-cabelling, i.e., mixing of two watermasses of the same density leads to a resulting watermass that is *less* dense.

   [2 marks]