OCES 2003 Assignment 1, Spring 2022

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Set on: Tue 24th Feb; due: Tue 03rd 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
- 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/midterm/final

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

  - 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 could result in an Academic Misconduct case being filed (see `https://acadreg.ust.hk/generalreg.html#b`)

Problems

1. Recall that 1 Sverdrup is 1 million cubic meters per second, i.e. 1 Sv = 10^6 m^3 s^{-1}. In these units, the ACC has around 130 Sv of transport, while the Gulf Stream is around 30 Sv (numbers rounded for simplicity).

   (a) Suppose you have a bathroom tap that is flowing with a speed of 1 m s^{-1}, where the opening has a cross section of 2 cm^2 (so it's a wide-ish tap). Work out the tap's transport in units of Sv, giving your answer accurate to the 2 decimal places but in the form exponential form, i.e. $a.bc \times 10^d$. [1 mark]

   (b) Suppose you have a river that is flowing with a speed of 7 miles hr^{-1} (a reasonably fast flowing river), and it is 50 m wide and 2 m deep. Work out the river's transport in units of Sv, giving your answer accurate to 2 decimal places but in the form exponential form, i.e. $a.bc \times 10^d$. Use 1 mile = 1600 m. [2 marks]

   (So the ACC and Gulf Stream is transporting a LOT of water.)

   (c) Suppose the ACC having that transport above is travelling through a cross-section that is 2000 km wide and 4000 m deep. What is the average speed of the ACC in standard units? Give your answer as a fraction or to three decimal places in the form $a.bcd$. [1 mark]

   (d) Suppose the Gulf Stream having that transport above is travelling through a cross-section that is 100 km wide and 1000 m deep. What is the average speed of the Gulf Stream in standard units? Give your answer as a fraction or to two decimal places in the form $a.bcd$. How does this compare to the implied average speed of the ACC above, and is this consistent with known values? Provide references accordingly if citing sources. [2 marks]

2. Consider the following graph showing sea level changes over long time-scales (a standard kind of graph you might see in the paleoclimate or paleo-oceanography literature):

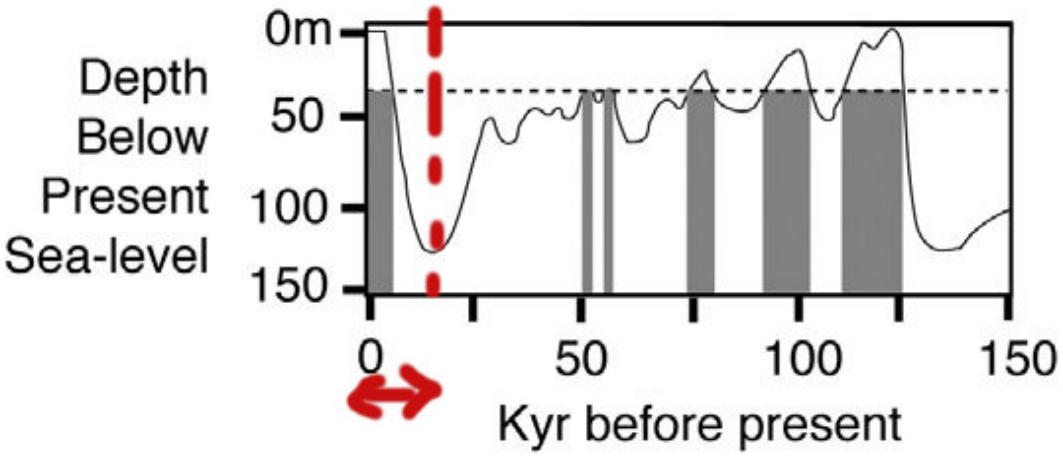

Figure 1: Eustatic sea level, from Harris *et al.* (2007), "*Submerged coral reefs and benthic habitats of the southern Gulf of Carpentaria.*"

Denoting η as sea level and t as time *going forward*, state the sign of $\partial\eta/\partial t$ within the region denoted by the red arrows (you can ignore the bit that is flat). If $\partial^2\eta/\partial t^2 > 0$ also in this region, what does that mean physically?

[3 marks]

3. With the standard convention in the course, through pictorial means or otherwise (but show your working), find the answer to the following (give your answer in a direction, but you don't need to bother about the magnitude):

   (a) East × North = ?

   (b) North × West = ?

   (c) (South-West) × East = ?

   (d) ? × North = West [2 marks]

4. This one is somewhat about river forcing on the oceans.

   (a) List the world's five largest rivers by *average river discharge* (i.e. rate of volume of freshwater input) into *oceans* or *seas*, giving the names of the rivers as well as their discharge rate in units of Sverdrups. List all the sources you do use. (Hint: The Yangtze river should be in the list.)

   [2 marks]

   (b) Taking those largest five rivers and assuming average discharge rates, work out how much mass is being dumped into the ocean by those rivers over one year (assume 365 days), assuming all the mass is in the form of freshwater with no impurities dissolved in it. Give your answer in units of kg accurate to 2 decimal places in the exponential form, i.e. $a.bc \times 10^d$. (Hint: Freshwater has a well-defined density at 4° C that you can look up.)

   [2 marks]

5. The **specific heat capacity** c_p is the amount of energy (in Joules, J) required to raise a kg of material by 1 Kelvin (or 1 degree Celsius, doesn't matter). Standard water has $c_p \approx 4,200$ J kg^{-1} K^{-1} (which by the way is essentially the definition of the *calorie*), while for seawater we have $c_p \approx 3,800$ J kg^{-1} K^{-1}. For simplicity you can take $c_p = 4,000$ J kg^{-1} K^{-1} for this question.

   (a) Suppose you want to make some of that famous Hong Kong style milk tea, and you want to boil say 300 ml of water (you can assume this has density of freshwater at 4° C; see Q4*b*), raising it from 20° C to 100° C. Using the value of c_p above, how much energy do you need to put in? Give your answer to the nearest kJ = 10^3 J. [2 marks]

   (b) Suppose your kettle has **power** (units of W = J s^{-1}) of about 700 W, somewhat standard of a kettle. How long does it take to boil that water so you can make that cup of Hong Kong style milk tea (assuming perfect efficiency and no loss etc.)? Give your answer to the nearest minute (have a think also whether the answer you get is sensible). [1 mark]

   (c) Using a similar logic, we know that the solar radiation has a power input of about 340 W m^{-2} at the top of the atmosphere of Earth, and if we take the ocean as having a surface area of 361 million km^2, with the freshwater density as above, and supposing all that solar energy is applied over a day and completely and perfectly absorbed over a 1 m depth of the ocean, show that the implied temperature change of seawater is about 7° C. (Hint: It might be helpful to work with symbols first, as you will realise one of the pieces of information is essentially redundant.) [2 marks]

   (d) So in reality you never get remotely close to that temperature change. Give some dynamical and/or physical reasons on why the above is a massive over-estimate. Cite any sources that you use (if you use them). [2 marks]

!? (No marks bonus question; adapted from "*What if*?" by Randall Monroe, creator of XKCD.) Going back to the cup of tea example, the argument is that if you stir some water, you are imparting some energy into it, which will lead to some heating. Suppose you assume all the kinetic energy you put in from stirring gets completely transferred into heat, and miraculously there is no heat loss whatsoever from your cup of tea via thermodynamic or mechanical processes. Estimate how long it would take to boil the cup of water, supposing you start the water at 20° C. (Hint: For this you need an estimate of the power input from you stirring.)

Do a similar thing for the ocean, but look up the estimated stirring power by marine organisms in the ocean. This webpage (`https://nerc.ukri.org/planetearth/stories/130/`) may be a good place to start.