OCES 2003 Assignment 1, Spring 2024

Julian Mak (`jclmak@ust.hk`)

Set on: Mon 19$^{\text{th}}$ Feb; due: Mon 26$^{\text{th}}$ Feb

Model solutions and mark scheme

1. (a) To get a volume flux (in units of $\mathrm{m}^3\ \mathrm{s}^{-1}$) from flow and the given area you simply multiply the two, but noting that you need to convert units:

$$(1.5\ \mathrm{m\ s}^{-1})(1\ \mathrm{cm}^2) = (1.5\ \mathrm{m\ s}^{-1})(10^{-2}\ \mathrm{m})^2 = 1.5\times 10^{-4}\ \mathrm{m}^3\ \mathrm{s}^{-1} = 1.50\times 10^{-10}\ \mathrm{Sv}.$$

(0.5 marks for getting answer and convert units properly, 0.5 marks for giving answer in the form requested.)

(b) Here we need a conversion of the velocity. The cross section is simply $30\times 10^3\times 10 = 3\times 10^5\ \mathrm{m}^2$, and

$$5\ \mathrm{miles\ hr}^{-1} 3\times 10^5\ \mathrm{m}^2 = \frac{5\cdot 1600\ \mathrm{m}}{3600\ \mathrm{s}} 3\times 10^5\ \mathrm{m}^2 = 0.66\ \mathrm{Sv} = 6.67\ \times 10^{-1}\ \mathrm{Sv}.$$

(1 mark for getting answer and convert units properly. Give only 0.5 marks if answer written as 0.66 or 0.67 Sv.)

(c) I make it a volume of $3.75\times 10^{15}\ \mathrm{m}^3$ and an inflow of $10^4\ \mathrm{m}^3\ \mathrm{s}^{-1}$. To get a time out, take the volume divided by the inflow, which I make it to be $3.75\times 10^{11}\ \mathrm{s}^{-1}$. Dividing that by $3600\times 24\times 365$ (to per year) I get about 12,000 years, which to the degree of accuracy required is 10,000 years.

(Or, even more rough, one year is about 3×10^7 s, so we would have about $3\times 10^1 1/3\times 10^7 = 10^4 = 10,000$ years.)

Contrast this to the Zanclean flood for example.

(0.5 marks for getting answer and convert units properly, 0.5 marks for giving answer in the form requested.)

2. The map is from Legend of Zelda: Breath of the Wild (although Tears of the Kingdom uses an essentially similar map.)

   (a) Negative (because you want going West means you go up the hill, while going East takes you down the hill)
   (b) Positive (because going up the hill)
   (c) North East or South West (because you want to stay at the same height)
   (d) Maximum gradient in this case would be *steepest* descent, which happens when you go North
   (e) No such direction exists, because going in any direction would be going down hill

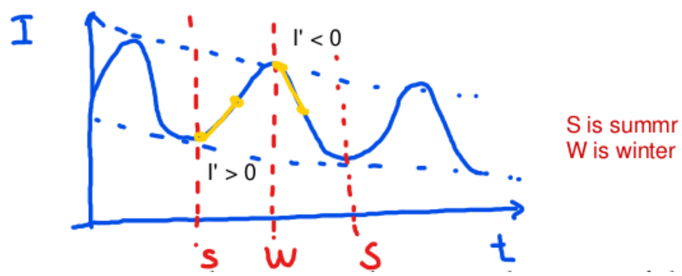
   (1 marks each. Give half marks if wrong answer but ok explanation, assuming it exists)

3. No flow would be one answer. Uniform constant flow in one direction would be another. (Answer is as in Lecture slide 4.)

   More complicated ones exist; see bonus question below.

(1 mark for a valid answer, and 1 mark for explanations).

4. (a) See graph from Jonathan. Ice should be growing between peak summer and winter, so the derivative would be positive, and is negative for the other case for the converse reason.



(1 mark for graph, 0.5 marks each for the signs. Downward trend not necessary for the mark for the graph, as question is mostly asking for the seasonal cycle.)

(b) Decreasing trend would be a negative derivative.

(1 mark.)

(c) Sea ice already displaces water by floating in it, so if it melts it's not really changing the volume. Another argument I suppose could be that sea ice is formed from sea water anyway, so when you melt it it's just adding to whatever was taken out in the first place.

(1 mark for similar answers.)

(d) Sea ice melting releases fresh water into the ocean, so it would *decrease* the salinity, which would lighten the water. The water would be expected to be *more convectively stable*, because the buoyancy gradient has increased.

(0.5 mark for decrease salinity, 0.5 mark for lighten water, 1 mark for more convectively stable.)

(e) This question is deliberately ambiguous, and answer could be either or both.

Generally we would expect the ice to act as a blanket shielding the ocean water from the cooler atmosphere. If ice disappears, we might suspect ocean would *lose* heat to the atmosphere. However, having no ice means it is possible for a direct heating by radiation on the ocean, so it is plausible that water could *gain* heat. I would assume the former scenario is more likely the actual result, because convective lost (wind taking heat away for example) would trump the radiative gain.

(2 marks for either answer but only if it is sufficiently justified. Give a bonus mark if student provides both possibilities, and another bonus mark if they argue one is more likely than the other.)

(f) Meneghello *et al.* (2018) and related papers would do it. Absence of sea ice exposes the ocean to the wind, allowing for direct momentum transfer from the atmosphere to the ocean, leading to a momentum gain of the ocean from the atmosphere (which we might call a spin-up of the gyre).

On the other hand, when sea ice forms during winter, the shielding effect as well as friction between the ocean and *ice* would be expected to lead to a momentum loss from the ocean to the *ice* (which we might call a spin-down of the gyre).

There is some talk about the implications for this for the *Beaufort Gyre*, which holds a large reserve of freshwater content in the ocean, and how changes to the Beaufort Gyre circulation could lead to freshening of the surrounding waters and affecting the circulation.

(1 mark for at least a reference, 1 mark for spin-up mechanism, 1 mark for spin-down mechanism, and 1 mark as appropriate for writing/grammar/spelling.)

!? (No marks bonus question.) The first derivative being zero tells you about what are known as stationary points (e.g. max or mins), while the second derivative tells you information about whether a stationary point is a maximum or a minimum (in the multidimensional case this is encoded in what is called the *Hessian*). For Q2*e* the second derivatives should be negative, and if we are in a trough it is positive. The answer depends if we are dealing with a saddle (it's all really to do with eigenvalues of the Hessian.)

!? Look up harmonic functions and solutions of the Cauchy–Riemann equations. The *streamlines* $\psi =$ constant of the *streamfunction* ψ are harmonic functions and solutions to $\nabla^2\psi = 0$, where the velocity field could be thought of as the flow that is everywhere parallel to the streamlines.