**Candidates are admitted to the examination room ten minutes before the start of the examination. On admission to the examination room, you are permitted to acquaint yourself with the instructions below and to read the question paper.**

**Do not write anything until the invigilator informs you that you may start the examination. You will be given five minutes at the end of the examination to complete the front of any answer books used.**

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April 2011

Answer Book
General Data Sheet
Any bilingual English language dictionary permitted
Only Casio-fx83 calculators are permitted

# THE UNIVERSITY OF READING

MSc Examination for Courses in Sciences

Oceanography

## MTMG21

2 hours

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Answer **ANY TWO** questions

The marks for the individual components of each question are given in [ ] brackets. The total mark for the paper is 100

1.

(a) Write down the equations of geostrophic balance and hydrostatic balance, defining each of the symbols involved.

Hence show that the zonal geostrophic velocity as a function of depth is given by,

$$u(z) = u_{ref} + \frac{g}{\rho_0 f} \int_{z_{ref}}^{z} \frac{\partial \rho}{\partial y} dz'$$

[10 marks]

(b) Describe how a hydrographic section is carried out including which quantities are typically measured so that the sea-water density can be determined. [5 marks]

(c) Assume that the density of seawater can be approximated by the expression:

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

where $\alpha = 10^{-4}\ K^{-1}$, $\beta = 0.8 \times 10^{-3}\ (g/kg)^{-1}$, and $\rho_0$, $T_0$ and $S_0$ are constant.

A hydrographic section has been carried out in the meridional direction across the Antarctic Circumpolar Current. It is observed that horizontal temperature and salinity gradients are independent of height with a dependence on distance given by:

$$T - T_0 = A(y - y_0) \quad \text{and} \quad S - S_0 = B\left( y_0 - y \right)$$

where $y_0$ is the location of the start of the section.

Show that u(z) is therefore given by the expression:

$$u(z) = u_{ref} - \frac{g}{f}\left( z - z_{ref} \right)\left( \alpha A + \beta B \right)$$

[15 marks]

Question 1 continued overleaf

Question 1 cont'd.

(d) If it is observed that $A=2x10^{-6}$ $K.m^{-1}$, $B=3x10^{-7}$ $g/kg.m^{-1}$ and that the observed current at a depth of 4 km can be taken to zero, find the sea surface current.

[10 marks]

(e) Describe briefly three other methods for measuring ocean properties, highlighting the advantages and disadvantages of each.

[10 marks]

2. A square ocean with solid boundaries located at x=0,L and y=0,L is exposed to a zonal wind stress at its surface,

$$\tau_s = -\tau_0 \cos\left(\frac{\pi y}{L}\right)\mathbf{i}$$

where $\tau_0$ = 0.2 N.m$^{-2}$, and **i** is the unit vector in the zonal direction.

(a) Write down the equation of Sverdrup balance. Define a streamfunction $\psi$ such that $\int_{-H}^{0} v\,dz = \frac{\partial \psi}{\partial x}$. Adopting suitable boundary conditions, show that

$$\psi = \frac{\pi\tau_0}{\rho_0 \beta L}(L-x)\sin\left(\frac{\pi y}{L}\right)$$

Sketch $\psi$(x,y).

[20 marks]

(b) By using the result of part (a), show that the maximum southward transport of the gyre predicted by Sverdrup balance is:

$$T = \frac{\pi\tau_0}{\rho_0 \beta}$$

and calculate T, giving your answer in Sverdrups ($\beta$=2x10$^{-11}$ m$^{-1}$s$^{-1}$)

[20 marks]

(c) Suppose that the gyre is closed by a frictional boundary current of width $\delta \sim r/\beta$ where r=10$^{-7}$ s$^{-1}$.
Estimate a typical boundary current velocity (assume a typical value for the ocean depth).

[5 marks]

Question 2 continued overleaf

Turn over



Question 2 cont'd.

(d) What would happen to the location of the western boundary currents if the sign of Earth rotation was reversed? (with everything else staying the same). Would the total transport associated with the western boundary currents increase or decrease if Earth rotation was halved? In each case, motivate your answer.

[5 marks]

3. Give a brief explanation of each of the following. There is no need to give mathematical details, but your answers should describe the underlying physical principles in each case.

(a) The presence of a sound channel in the oceans.

[10 marks]

(b) The location of the world's major fisheries on the eastern margins of ocean basins.

[10 marks]

(c) Why the T-S properties of the ocean interior match those of the winter mixed layer.

[10 marks]

(d) Why are the Atlantic meridional overturning circulation (AMOC) and subtropical ocean gyres thought to participate in the poleward heat transport. Using scaling estimates that you should justify, estimate the relative importance of the AMOC and wind-driven ocean gyres in contributing to the oceanic poleward heat transport.

[20 marks]

(End of Question Paper)