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.

April 2013 **MTMG21**

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

UNIVERSITY OF READING

Oceanography (MTMG21)

Two hours

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) Briefly summarise the mean principles and objectives of satellite altimetry and the underlying physical principles.

Explain what is meant by the “geoid”.

[10 marks]

(b) Write down the equations for geostrophic and hydrostatic balance in the ocean and clearly define every symbol.

Show that the surface geostrophic velocity can be estimated using

$$u = -\frac{g}{f}\frac{\partial}{\partial y}\left(\eta_{observed} - \eta_{geoid}\right)$$

$$v = \frac{g}{f}\frac{\partial}{\partial x}\left(\eta_{observed} - \eta_{geoid}\right)$$

and state any necessary assumptions.

[12 marks]

(c) Using typical midlatitude values ($f = 10^{-4} s^{-1}$, $L = 10^{6} m$, $U = 10^{-2} m\, s^{-1}$, $g = 10\ m\, s^{-2}$), estimate by how much ($\eta_{observed}$ - η_{geoid}) is likely to vary across an ocean basin.

How does your estimate compare with typical variations in η_{geoid}?

Explain why knowledge of η_{geoid} is not necessary for estimating the time-varying, rather than time-mean, surface geostrophic currents.

[12 marks]

(d) Give a physical explanation for the existence of a sound channel at a depth of approximately 1 km in the ocean.

Explain how this sound channel might be exploited to measure future changes in the large-scale structure of the oceans.

[16 marks]

2. (a) The vorticity equation for a homogenous ocean, forced by a zonal wind stress and dissipated by linear friction, can be written

$$\left(\frac{\partial}{\partial t}+\mathbf{u}\bullet\nabla\right)\zeta=-\frac{1}{\rho_0 H}\frac{\partial\tau_s^{(x)}}{\partial y}-r\zeta.$$

Define each of the symbols in this equation and give a physical interpretation of each term.

[10 marks]

(b) Write down the "Sverdrup balance" that holds approximately in the interior of an ocean gyre.

Clearly state and justify the approximations required to neglect the omitted terms.

Assuming that the wind stress varies only with latitude, show that the northward transport predicted by Sverdrup balance is

$$T=-\frac{L}{\beta\rho_0}\frac{\partial\tau_s^{(x)}}{\partial y}$$

where L is the basin width and β has its usual meaning.

Sketch the circulation predicted by Sverdrup balance in a typical ocean basin, stating clearly any boundary conditions that you assume.

Estimate T for a subtropical gyre, assuming a wind stress of magnitude 0.1 N m^{-2} and typical values for the remaining parameters.

[25 marks]

(c) Suppose that the gyre is closed by a frictional boundary current. By discussing a solution of the vorticity equation, deduce that the width of the frictional boundary current is

$$\delta \sim \frac{r}{\beta}.$$

Assuming $r = 10^{-7}$ s^{-1} and H=2000 m, estimate δ and a typical boundary current velocity.

Using these answers, estimate the magnitude of the relative vorticity in the boundary current, and deduce that it cannot be neglected.

[15 marks]

3. Give a brief explanation (up to half a page) 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) Why mesoscale eddy activity should not be neglected in ocean climate models, and how it can be accounted for.

[10 marks]

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

[10 marks]

(c) Why the Atlantic meridional overturning circulation (AMOC) and subtropical ocean gyres are 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]

(d) Why is there upwelling of deep water masses in the Southern Ocean? How is this upwelling related to the AMOC? Is there a process that opposes the upwelling?

[10 marks]

[End of Question paper]