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 2014 **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. The observed stratification in temperature of the ocean is generally assumed to result from a balance between downward diffusion of heat and upward advection of cold water, as described by the following advection diffusion equation:

$$w\frac{\partial T}{\partial z} = K\frac{\partial^2 T}{\partial z^2} \quad \text{(Eq. 1)}$$

(a) Define the physical meaning and physical units for each symbol appearing in Equation 1 above.

[5 marks]

(b) We assume that z=0 at the ocean surface, and that z increase upward. A good analytical fit for the observed vertical temperature profile is given by the following exponential vertical profile, where T_0, ΔT and d are constant:

$$T(z) = T_0 + \Delta T \exp\left\{\frac{z}{d}\right\} \quad \text{(Eq. 2)}$$

(i) Show that the function defined by Eq. (2) satisfies the advection diffusion equation Eq. 1 under some conditions that you should state explicitly.

(ii) An oceanographer would like to determine the three constants T_0, ΔT and d entering Eq. 2. What is the minimum number of observations of T(z) in the vertical that are needed to determine these three constants? Explain how you arrive at your answer.

(iii) It has been established that the best fit for the constant d was d=500 m; it is also observed that T(z)=20^{o}C at z=0 and that T(z) = 10^{o}C at z=-1000 m. Determine the values of T_0 and ΔT.

[15 marks]

(c) The deep water formation rate is estimated to be 25 Sverdrups (Sv). By invoking mass conservation, estimate the mean value of w necessary to return the flow through the interface between the deep and surface ocean, assuming that the surface area of the interface is $A = 2.10^{14}$ m^2. Deduce the corresponding value for K if d has the value given in question (b)(iii) above.

[10 marks]

(d) Estimate the magnitude of the heat transport in the Atlantic ocean associated with the meridional overturning circulation, assuming a horizontal mass transport of 25 Sverdrups. State all necessary assumptions to do such a calculation.

[8 marks]

(e) Is there any transport of heat associated with the wind-driven circulation of the subtropical gyre? You should justify your arguments. If yes, is the heat transport northward or southward, and can you provide an order of magnitude, stating all necessary assumptions?

[12 marks]

2. (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,

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

[15 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.

[6 marks]

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

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

where $\alpha=10^{-4}$ K^{-1}, $\beta=0.8 \times 10^{-3}$ $(g/kg)^{-1}$, and ρ_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:

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

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

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

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

[10 marks]

(d) Estimate the velocity at the ocean surface at midlatitude, assuming $A=2\times10^{-6}$ $K.m^{-1}$, $B=3\times10^{-7}$ $g/kg.m^{-1}$ and a reference level of no motion at 4km.

[10 marks]

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

[9 marks]

3. General knowledge about the ocean circulation

(a) Discuss the physical processes determining the variations of sea level at any given point in the oceans. Among these processes, identify those that cancel out when averaged globally, as well as the processes relevant only to mean global sea level change.

[10 marks]

(b) What is the geoid and explain why it is important for the understanding the ocean circulation? In your discussion, you should distinguish between steady-state and transient processes.

[10 marks]

(c) What is acoustic tomography, and what is its principle? Can acoustic tomography be used to monitor the temperature at a single point in the ocean?

[10 marks]

(d) Discuss the physical principles responsible for the observed intensified ocean currents along western boundaries.

[10 marks]

(e) Discuss the physical principles important for understanding the thermohaline circulation of the ocean, and explain the relative importance of the wind and the buoyancy forcing in driving it.

[10 marks]

(End of Question Paper)