Geophysics 424 Mid-term exam
Wednesday February 26, 2014

Name ____

Student number ______________________________

*Time allowed : **80 minutes**.*

*Attempt all **FIVE** questions*

Note the number of points allocated for each part.

Calculators and rulers may be used

Notes and textbooks may not be used during the exam

Explain your answers

Please hand in this exam, with your name and student number listed above

Total points for whole exam = 68

Question 1 – Resistivity of rocks (Total = 12 points)

A fractured rock has a porosity, Φ and is saturated with brine.

The brine has a resistivity of $\rho_0 = 1\ \Omega\text{m}$

The rock matrix has a resistivity of $\rho_1 = 1000\ \Omega\text{m}$.

The brine is located in **cracks.**

Consider a cube of rock that is 1 m *x* 1m *x* 1m

(1a) Derive an equation for the **resistance** of the cube when electric current flows **parallel** to the cracks. Consider $0 < \Phi < 1$ **(3 points)**

(1b) Derive an equation for the **resistance** of the cube when electric current flows **normal** to the cracks. Consider $0 < \Phi < 1$ **(3 points)**

(1c) Sketch these resistance values on a graph for the **range** $0 < \Phi < 1$ **(4 points)**

(1d) What is the salinity of the brine? **(2 points)**

Question 2 – Boundary conditions (Total = 8 points)

A **horizontal** interface separates regions with conductivity σ_1 and σ_2

(2a) Show that the **horizontal electric field** is continuous across the interface

Question 3 : Maxwell's equations (Total = 16 points)

A plane EM signal is travelling vertically downwards, in the z-direction.

At this location, the resistivity of the Earth does not vary in the x-direction

The EM fields vary harmonically with time as $e^{-i\omega t}$ at an angular frequency ω

(3a) Expand **Ampere's Law** and **Faradays Law** to give **six** equations for the components of **E** and **B**. You can ignore displacement current **(6 points)**

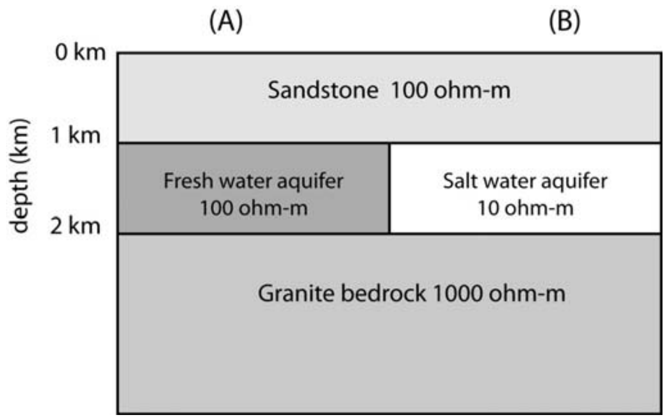
(3b) Consider the fact that there is no variation in the x-direction. Show that the **six equations** in (3a) can be separated in two sets of 3 equations. **(4 points)**

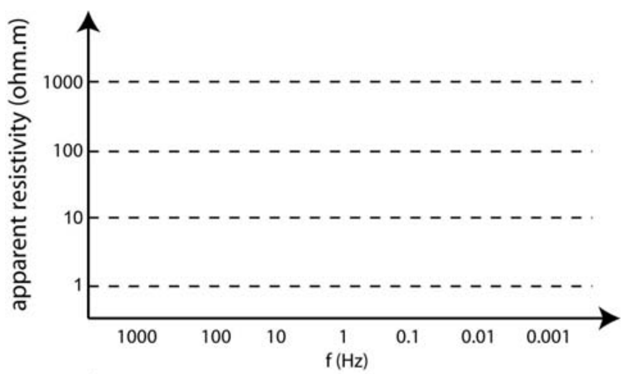
(3c) Select the 3 equations that include E_x and derive a second order differential equation for E_x **(4 points)**

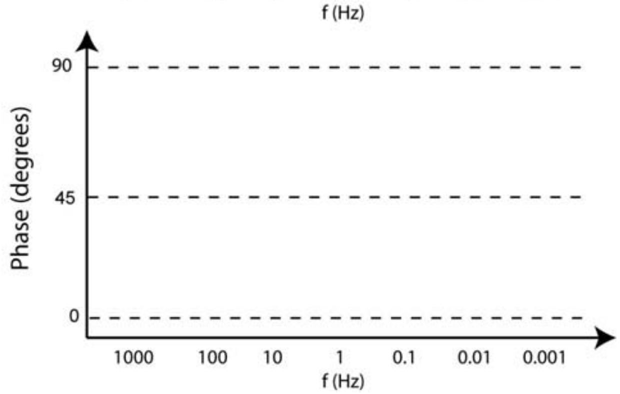
(3d) Which magnetotelluric **mode** does this represent? **(2 points)**

Question 4 : Magnetotellurics (Total = 17 points)

Broadband MT data are being used in groundwater exploration to map the intrusion of a saline aquifer.







(4a) Sketch the MT apparent resistivity and phase data at sites 'A' and 'B' on the graph above. The resistivity structure at each location can be considered 1-D.

Be quantitative where possible. **(17 points)**

Question 5 : Magnetotellurics (Total = 15 points)

(5a) What are the two types of sensor used to measure the magnetic field in magnetotellurics? **(2 points)**

(5b) Name the two sources of MT signals, and approximate frequencies **(4 points)**

(5c) An MT signal is being digitized with a sample rate of 1000 Hz. Recording continues for 2 hours. What are the maximum and minimum frequencies that can be obtained? **(4 points)**

(5d) In this context, what is saturation? Is it good or bad? **(3 points)**

(5e) The digitizer has a full scale range of 4 V and uses a 24-bit A-to-D converter. What is the weakest signal that can be detected? **(2 points)**