Geophysics 424   Mid-term exam
Wednesday February 29th 2012

Name ______________________________________

Student number _____________________________

*Time allowed : **55 minutes**.*

*Attempt all **FOUR** 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 all working

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

Total points for whole exam = 46

Question 1 – Resistivity of rocks (Total = 6 points)

A shale is partially saturated with brine
The shale has well connected pores with a porosity of 2%
Brine salinity = 10g per litre
The rock grains have a resistivity of 1000 Ωm
Well log measurements give a bulk resistivity is 45 Ωm

(1a) Use Archie's Law to calculate the degree of saturation (S) **(4 points)**

(1b) State two assumptions made in your answer to (a) **(2 points)**

Question 2 : Maxwell's equations (Total = 13 points)

A **plane** EM wave is travelling **vertically downwards** in the air in the *z*-direction. The electric field is **polarized** in the *x*-direction. The surface of the Earth is at $z = 0$

Magnetic permeability of air and Earth	$= \mu = \mu_0$
Dielectric permittivity of air and Earth	$= \varepsilon = \varepsilon_0$
Electrical conductivity of Earth	$= \sigma$
Angular frequency of wave	$= \omega$

Incident wave in air $E_x(z,t) = A \exp(-ik_o z)\, e^{-i\omega t}$
Reflected wave in air $E_x(z,t) = B \exp(ik_o z)\, e^{-i\omega t}$
Transmitted signal in Earth $E_x(z,t) = C \exp(-k_1 z)\, e^{-i\omega t}$

Wavenumbers in each medium are:

$k_o = \omega\sqrt{\mu\varepsilon}$ and $k_1 = (1-i)\sqrt{\dfrac{\omega\mu\sigma}{2}}$

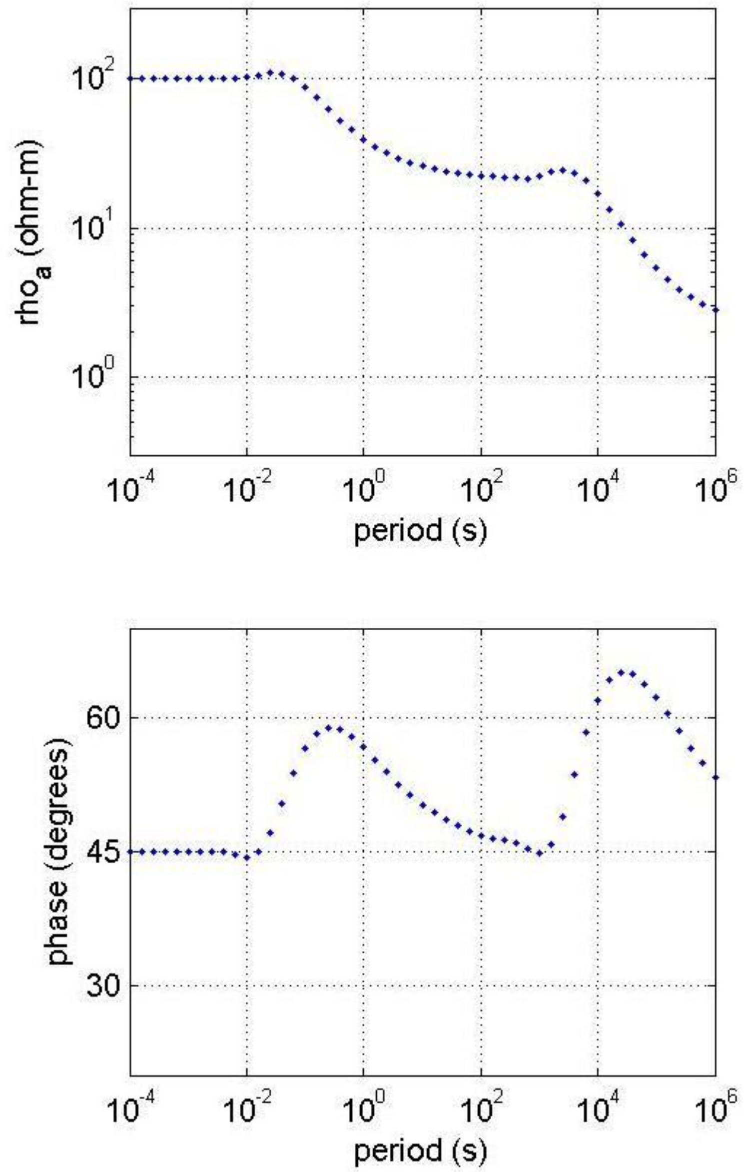
You can assume that $H_y = \dfrac{-1}{i\omega\mu}\dfrac{\partial E_x}{\partial z}$

(2a) State two boundary conditions that can be applied at z = 0 **(2 points)**

(2b) Derive an expression for C in terms of k_o, k_1 and A. **(7 points)**

(2c) Derive an expression for the impedance (Z_{xy}) in terms of ω, μ and σ **(4 points)**

Question 3 : Magnetotelluric sounding curves (Total = 15 points)



The figure above shows the MT data collected over a 3-layer Earth.
In (a)-(d), explain how you derived your answer.

(3a) Estimate the resistivity and thickness of the upper layer? **(4 points)**

(3b) Estimate the resistivity and thickness of the second layer? **(4 points)**

(3c) What can you determine about layer 3? **(3 points)**

(3d) Are the apparent resistivity and phase consistent? (Yes/No)
Explain your answer briefly **(4 points)**

Question 4 : Magnetotellurics (Total = 12 points)

(a) Why can it be difficult to use seismic reflection for subsalt imaging? Describe how MT exploration can be used effectively in this context. **(4 points)**

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

(c) MT data was recorded at three frequencies.

The apparent resistivity values were [ρ_1 ρ_2 ρ_3]
The data had uncertainties of [e_1 e_2 e_3]
The model that fit the data had a response of [m_1 m_2 m_3]

Write an expression for the **root-mean-square misfit** of the response to the data.

(4 points)