Geophysics 424 Mid-term exam
Tuesday October 14th 2008

Name _____

Student number _____

Time allowed : ***80 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.

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

Total points for whole exam = 65

Question 1 (Total = 10 points)

(1a) Name the **two** main sources of magnetotelluric signals. State the **frequency band** at which each occurs. **(4 points)**

(1b) How does the presence of **clay** change the resistivity of a rock? What is the physical basis for this? **(4 points)**

(1c) State **two assumptions** that are made when Archie's Law is used to estimate the resistivity of a water saturated rock? **(2 points)**

Question 2 – Resistivity of rocks (Total = 10 points)

A fractured rock has a porosity, Φ and is saturated with brine. The brine has a resistivity of $\rho_0 = 1$ ohm-m and the rock matrix has a resistivity of $\rho_1 = 1000$ ohm-m.

The brine is located in **cracks.** Consider a cube that is 1 m x 1m x 1m.

(2a) Derive an equation for the **resistance** of the cube when electric current flows **parallel** to the cracks. Consider $0 < \Phi < 1$ **(3 points)**

(2b) Derive an equation for the resistance of the cube when electric current flows **normal** to the cracks. Consider $0 < \Phi < 1$ **(3 points)**

(2c) Sketch these resistance values on a graph for the **range** $0 < \Phi < 1$ **(4 points)**

Question 3 : Maxwell's equations (Total = 25 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	$E_x(z,t) = C \exp(-k_1 z)\, e^{-i\omega t}$

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

(3a) What type of EM **signal propagation** is implied by the values of k_o and k_1? What type of electric current dominates in each case? **(4 points)**

(3b) State **two boundary conditions** that can be applied at $z = 0$ **(2 points)**

(3c) Starting from Maxwell's equations, show that for this wave:

$$H_y = \frac{-1}{i\omega\mu}\frac{\partial E_x}{\partial z}$$ **(4 points)**

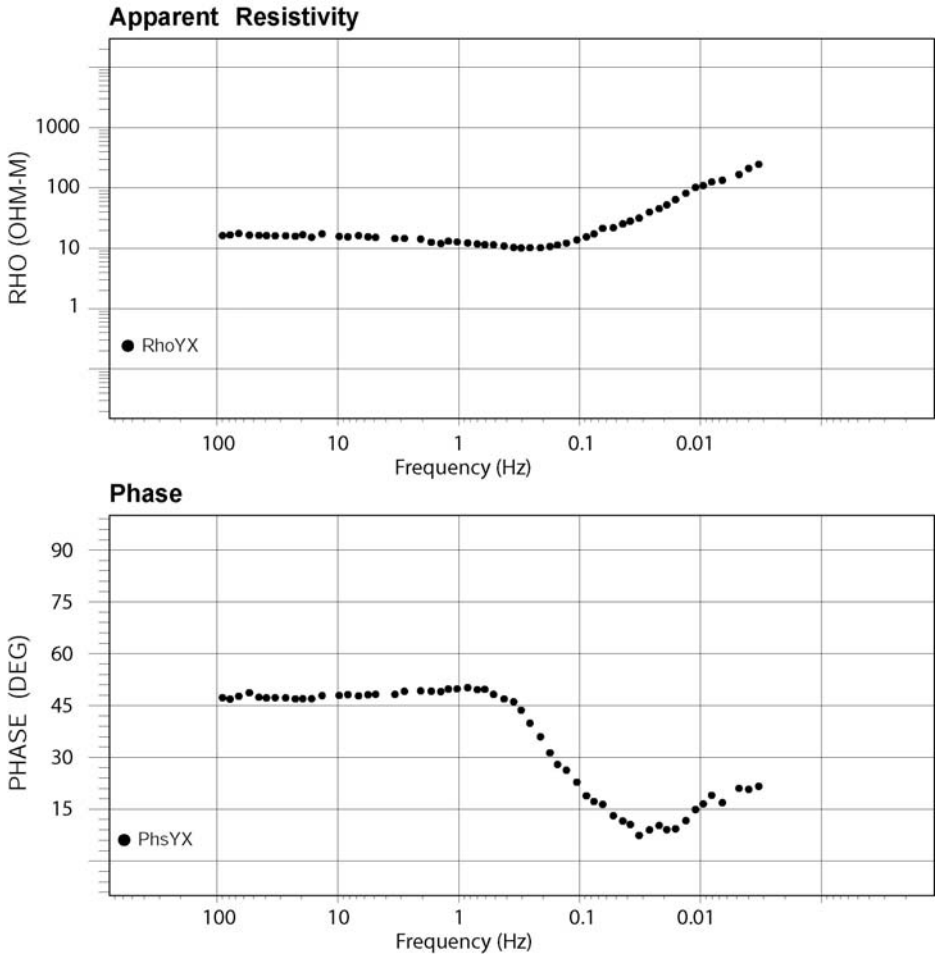
(3d) Derive an expression for C in terms of k_o, k_1 and A. **(7 points)**

(3e) Derive an expression for the Earth impedance (Z_{xy}) in terms of ω, μ and σ **(4 points)**

(3f) The **apparent resistivity** is defined as $\rho_a = \frac{1}{\omega\mu}|Z_{xy}|^2$.

Derive an expression for ρ_a and show that the has the expected value for a halfspace with conductivity = σ **(4 points)**

Question 4 : Magnetotellurics (Total = 20 points)



The figure above shows MT data recorded in the Western Canada Sedimentary Basin. The data can be interpreted in terms of a **2 layer model** (layer + halfspace).

In (4a)-(4g), explain how you derived your answer.

(4a) What **total recording time** and **sample rate** are needed to obtain these MT data? **(4 points)**

(4b) What is the resistivity of the upper layer? **(2 points)**

(4c) The resistivity of the upper layer is due to saline groundwater with resistivity of 0.3 ohm-m. Estimate the range porosity of this layer. **(4 points)**

(4d) How thick is the upper layer? **(2 points)**

(4e) What is the resistivity of the halfspace? **(3 points)**

(4f) What extra data is needed to determine if a 1-D analysis is valid? **(2 points)**

(4g) Are the apparent resistivity and phase data **consistent**? **(3 points)**