National Exams December 2014

04-Geol-A7, Applied Geophysics

3 hours duration

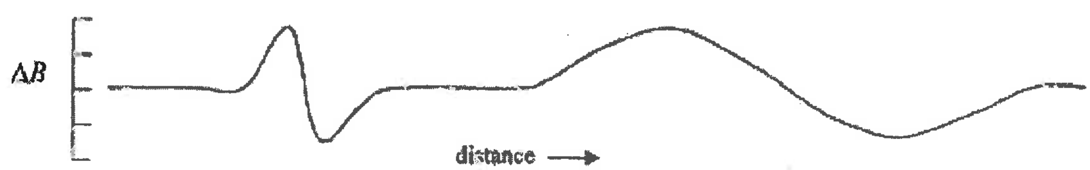
NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is an OPEN BOOK EXAM. Any non-communicating calculator is permitted.
3. SIX (6) questions constitute a complete exam paper. The first six questions as they appear in the answer book will be marked.
4. Each question is of equal value.
5. Most questions require an answer in essay format. Clarity and organization of the answer are important.

1. Answer the following short questions using a few sentences each (plus a sketch, where applicable):

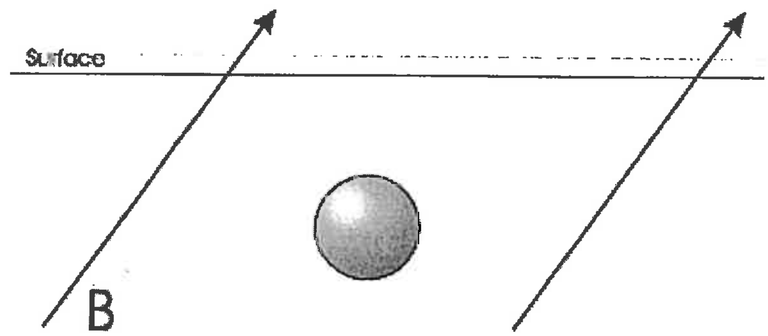
(i) Why do the readings of a gravimeter depend on latitude? Answer this i) for a stationary gravimeter, and ii) for a gravimeter in motion (e.g., on a ship or aircraft). In what way(s) are the readings corrected for these effects?
(ii) Draw a simple sketch showing why the induced magnetic field directly over the top of a buried magnetic anomaly opposes the earth's magnetic field at the equator (low latitudes), and re-enforces the earth's magnetic field near the poles (high latitudes)
(iii) Why would the Schlumberger electrode array configuration might be a good choice for depth profiling in the resistivity method, and why?
(iv) What advantages are there to time-domain electromagnetic (EM) methods, when compared with frequency-domain EM methods?
(v) What is a "shot gather" in a seismic reflection survey? What is a "common midpoint gather?
(vi) What two effects can cause a layer to be "hidden" in the seismic refraction method (assuming only first arrivals are analyzed)?

2. Answer all three parts below:
(i) Under what conditions would a terrain correction be required in order to accurately interpret the results of a gravity survey? [As a part of your answer, explain why it is exactly that the combination of free-air corrections and Bouguer corrections would not be sufficient].
(ii) Describe, with illustrations, Nettleton's method for estimating the density of near-surface rocks.
(iii) Two magnetic anomalies are shown in the profile below. Both are caused by sources having the same shape, size and direction of magnetization.



(a) Which anomaly is associated with the shallower source? Why?
(b) Which anomaly is associated with the source having the stronger magnetization? Why?
(c) How could you estimate the depth to each body based on the profile alone?

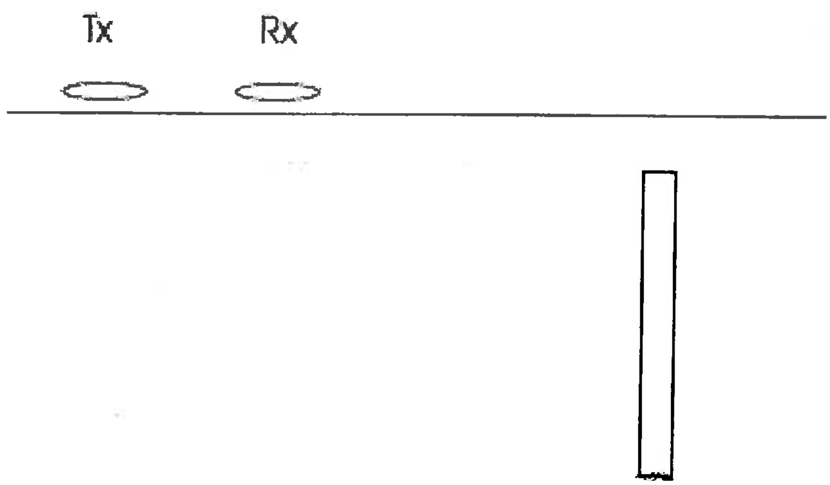
3. Answer both parts below:
   (i) Reproduce the Figure below in your answer books, and sketch the horizontal, vertical and total magnetic field anomalies over the top of this spherical-shaped ore body, assuming that the Earth's field induces the magnetization. Identify geographical north on the diagram. Is this in the northern or southern hemisphere?



   (ii) Name the most important class of rock magnetism in an exploration context, and give examples of minerals exhibiting these types of magnetism. Give a brief description, with sketches, of the origin of one of these classes of magnetism in terms of atomic-scale magnetic "domains".

4. Answer both parts below:
   (i) Explain the two mechanisms by which the Earth can store electrical charge (i.e. act as a capacitor and become electrically polarized). For each of these polarization effects, give an explanation in terms of the local accumulations of charged ions. For each mechanism, give geological examples and identify the utility of the effect in geophysical prospecting.
   (ii) Explain, with sketches, the two methods (time-domain and frequency-domain) that can be used to quantitatively measure the Induced Polarization effect. Make sure your sketches are labelled with the correct measurement units, and make sure your explanation contains suitable definitions of the terms "Chargeability", "Frequency effect" and "Metal Factor".

5. Answer all three parts below regarding the Figure below:

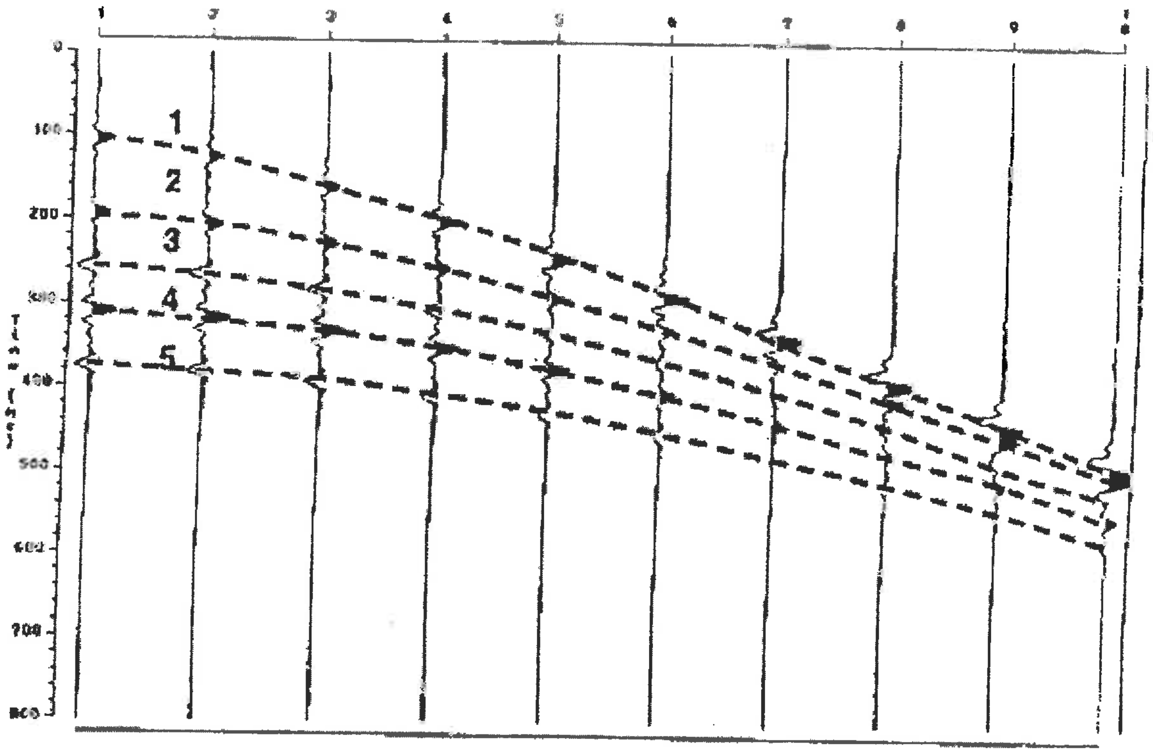


(i) Draw a sequence of figures similar to the Figure, showing the survey configuration as a traverse is carried out over the top of the conductive sheet, maintaining a fixed transmitter-receiver coil separation. Draw on these figures i) the primary field lines, arising from the transmitter loop and ii) the secondary field lines arising from the induced eddy currents in the conductive sheet.

(ii) Use the figures from part i) to sketch the expected field observations from the traverse. Your sketch should show profiles for both the In-phase and Out-of-phase components of the secondary field. You should assume that the conductor has a response parameter close to 10.

(iii) How would the In-phase and Out-of-phase profiles change if the response parameter for the target were reduced to 0.1?

6. Refer to the Figure below, and answer all three parts below:



The two-way time for events on a CMP gather increase with offset. A distinct Normal Moveout fits each reflector. The source-receiver offsets for the 10 traces are: 50 m, 150 m, 250 m, ..., 850 m, 950 m.

(i) Calculate from these data the velocity of the first layer and the depth to the first interface? [Hint: you require the use of the \Normal Moveout" equation.]

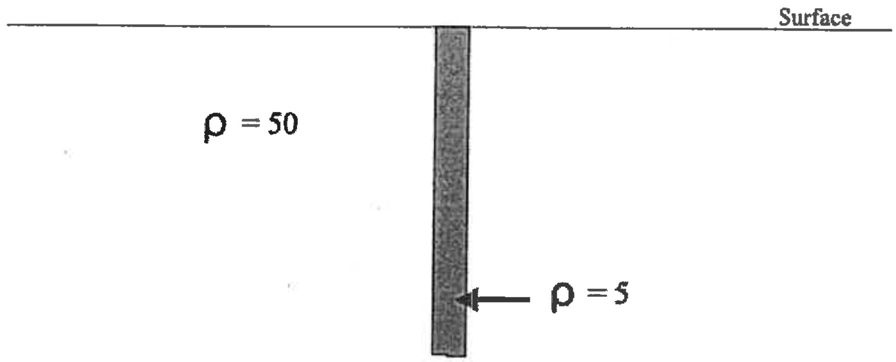
(ii) What is the approximate RMS velocity down to the base of the second layer? Use this to calculate the interval velocity of the second layer and the depth to the base of the second layer. [Hint: you require the use of the "Dix equation"].

(iii) A "velocity spectrum" is often used to aid in velocity analysis. Describe the manner in which a velocity spectrum is calculated. Sketch the appearance of the velocity spectrum that would result from the data in the Figure. Make sure your sketch is as quantitative as possible, label your axes correctly and indicate where on the spectrum the peaks in semblances would occur.

7. Answer all three parts below:

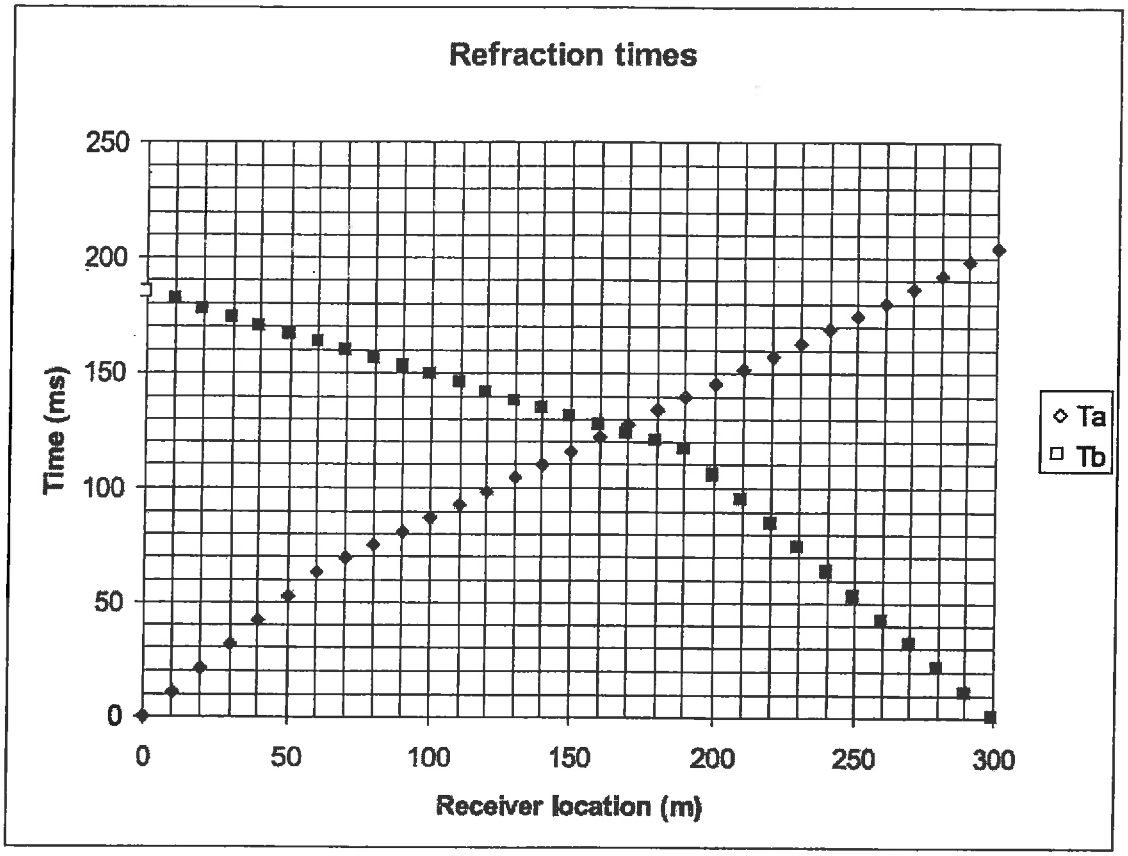
(i) Illustrate with sketches the expected appearance of resistivity depth-sounding surveys over 2-layer and 3-layer geological models. Present your results with appropriate graphs, with axes labeled accordingly. What electrode array configuration would you recommend for such a survey?

(ii) For the geological model illustrated in the Figure below, sketch the expected appearance of a dipole-dipole resistivity pseudo-section recorded across the top of the structure. (Note: the sketch need not be quantitatively accurate - a qualitative prediction is all that is required).
Give some explanation of the utilities, and limitations of pseudo-sections.



(i) Explain the inverse-modelling, or "inversion" approach to the interpretation of resistivity or IP data, and explain the utility of such an approach. Such results are sometimes referred to as "real sections", or electrical resistivity tomography.

8. The Figure below shows the observed first arrival times for a reversed refraction profile. Ta are the times from a source located at the left end of the line, and Tb are the times from a source located at the opposite end of the line. Using this Figure, answer both parts below:



(i) Give a qualitative interpretation of the data, in terms of the number of layers and any dip on the structure. Explain exactly what features of the data lead you to the interpretation.

(ii) Carry out a quantitative analysis of the data, establishing the seismic velocity of the layers, the dip of any interfaces and the vertical depth to any boundaries from the source locations.

Miscellaneous formulae and constants

Gravity

$$G = 6.67 \times 10^{-11} N \cdot m^2 \cdot kg^{-2}$$
$$\mathbf{F} = -G\frac{m_1 m_2}{r^2}\hat{\mathbf{r}}$$
$$\mathbf{F} = \nabla U$$
$$\nabla^2 U = 0$$
$$g_B = g_{obs} - g_t + (\Delta g_L + \Delta g_{FA} - \Delta g_B + \Delta g_T)$$
$$g_t = g_o(1 + \alpha \sin^2 2\phi + \beta \sin^2 2\phi)$$
$$g_o = 9.7893 \times 10^5 \text{ mGal/km} \quad \alpha = 5.3024 \times 10^{-3} \quad \beta = 5.9 \times 10^{-6}$$
$$\Delta g_L = 0.811 \sin 2\phi \text{ mGal/km} \quad \Delta g_B = 0.0419\rho \text{ mGal/m}$$
$$\Delta g_{FA} = 0.3086 \text{ mGal/m} \quad \rho \approx 2.67 \text{ gm/cm}^3$$
$$\delta g = \frac{\partial g}{\partial s}\,\delta s = \frac{K}{m}\frac{b}{a}y\frac{z}{s}\,\delta s$$
$$\Delta g_{max} = G\frac{\Delta\rho V}{z^2} = G\frac{M_e}{z^2}$$
$$M_e = \Delta\rho\frac{4}{3}\pi r^3$$
$$z \leq 1.3\, x_{\frac{1}{2}}$$
$$M_e = \frac{1}{2\pi G}\sum_{i=1}^{N}\Delta g_i \Delta a_i$$
$$\begin{aligned} M_e &= 25.3\ \Delta g_{max}\, x_{\frac{1}{2}}^2 \quad [tonnes] \quad (\text{gravity in } gu) \\ &= 253\ \ \Delta g_{max}\, x_{\frac{1}{2}}^2 \quad [tonnes] \quad (\text{gravity in } mGal) \end{aligned}$$
$$M_T = \frac{\rho_1}{(\rho_1 - \rho_2)}M_e$$
$$d_{2D} \leq 0.65\left|\frac{\Delta g_{max}}{(\partial g/\partial x)_{max}}\right| \quad d_{3D} \leq 0.86\left|\frac{\Delta g_{max}}{(\partial g/\partial x)_{max}}\right|$$

Magnetics

$$F = \left(\frac{\mu_0}{4\pi}\right)\frac{q_1 q_2}{r^2}$$
$$\mathbf{B} = -\nabla W$$
$$\nabla^2 W = 0$$
$$B_r = \left(\frac{\mu_0 M}{2\pi r^3}\right)\cos\theta \quad B_\theta = \left(\frac{\mu_0 M}{4\pi r^3}\right)\sin\theta$$
$$\mathbf{H} = \frac{\mathbf{B}}{\mu_0} - \mathbf{M}$$
$$\mathbf{M} = k\mathbf{H}$$
$$\mathbf{B} = \mu_0(1+k)\mathbf{H}$$
$$\mu_0 = 4\pi \times 10^{-7} Wb/A \cdot m$$

Seismics

$$k = \frac{E}{3(1-2\nu)}$$

$$V_p = \left(\frac{k + \frac{4}{3}\mu}{\rho}\right)^{\frac{1}{2}} \qquad V_s = \left(\frac{\mu}{\rho}\right)^{\frac{1}{2}}$$

$$\frac{V_p}{V_s} = \left[\frac{2(1-\nu)}{(1-2\nu)}\right]^{\frac{1}{2}} \qquad \nu = \frac{\left(\frac{V_p}{V_s}\right)^2 - 2}{2\left[\left(\frac{V_p}{V_s}\right)^2 - 1\right]}$$

$$\lambda = \frac{v}{f} \qquad \frac{\sin\theta_1}{v_1} = \frac{\sin\theta_2}{v_2}$$

$$t = x\,\frac{\sin(\theta_c \pm \delta)}{v_1} + \frac{2z\cos\theta_c}{v_1} \qquad t_n = \frac{x\sin\theta_1}{v_1} + \sum_{i=1}^{n-1}\frac{2z_i\cos\theta_i}{v_i}$$

$$t = t_0 + \frac{x^2}{2V_{rms}^2 t_0}$$

$$V_{rms_n} = \left[\frac{\sum_{i=1}^{n} v_i^2 \tau_i}{\sum_{i=1}^{n} \tau_i}\right]^{\frac{1}{2}}$$

Dix formula:

$$v_n = \left[\frac{V_{rms_n}^2 t_n - V_{rms_{n-1}}^2 t_{n-1}}{t_n - t_{n-1}}\right]^{\frac{1}{2}}$$

Electrical and Electromagnetics

$$\rho = R\left(\frac{A}{l}\right)$$

$$\mathbf{J} = -\left(\frac{1}{\rho}\right)\nabla V = -(\sigma)\nabla V = \sigma\mathbf{E}$$

$$V(r) = \frac{\rho I}{2\pi r}$$

$$\rho_a = 2\pi k\frac{\Delta V}{I} \quad k_{Wenner} = a \quad k_{Dipole} \approx n^3 a$$

$$\varepsilon = -\frac{d\Phi}{dt} = -\frac{d}{dt}\int\int_A \mathbf{B}\cdot d\mathbf{A}$$

$$\tan\phi = \frac{\omega L}{R} \qquad \tan\phi = \sigma\mu\omega a^2 \qquad \tan\phi = \sigma\mu\omega t l$$

$$\tau = L/R \quad \tau = \sigma\mu a^2 \quad \tau = \sigma\mu\omega t l$$