University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

PET110
Geophysics and Well logging

Final examination

03.05.2017

9.00 – 12.00

Tjodhallen – Kjølv Egelands hus,

and D-106 PC-rom

Permitted aids: Language dictionaries, approved calculators

THE EXAM CONSISTS OF 6 PAGES (Excluding this one)

Read the whole exam before you start, and try to answer the questions you find are the easiest first. Write in English or Norwegian. Useful formulas can be found on the last page of the exam.

Good luck.

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Problem 1

30% Plane harmonic waves, sampling and aliasing

a) 5% If a signal is sampled with a 1 ms sampling interval, what is the highest frequency in the signal that can be accurately reconstructed from the samples? (Select one of the choices below)

   1) 0.5 Hz
   2) 125 Hz
   3) 250 Hz
   4) 500 Hz

b) 10% What is the difference between P- and S-waves? In land and ocean bottom seismic acquisition there is a common assumption that the vertical component of the geophones measure mostly P-waves, whereas the horizontal components measure mostly S-waves. Make a sketch and explain with words why this is normally a useful approximation. Mention also a situation where this is not a good approximation.

c) 10% A geophone capable of recording the displacement field (movement of the ground) in three orthogonal directions gives the following temporal recording:

$$
\begin{aligned}
u_x &= 0, \\
u_y &= 0, \\
u_z &= A \sin \frac{2\pi}{\lambda}(z - vt),
\end{aligned}
\tag{1}
$$

   where $\vec{u} = (u_x, u_y, u_z)$ is the displacement of the ground in x, y, and z directions, λ is the seismic wavelength, A is the amplitude of the sine wave, v is the phase velocity, and t is the time. Using this information select which of the alternatives is the correct (only one of them is correct):

   1) The recording shows a P-wave traveling in the x direction.
   2) The recording shows a S-wave traveling in the x direction.
   3) The recording shows a P-wave traveling in the z direction.
   4) The recording shows a S-wave traveling in the z direction.

d) 5% A measure of vertical resolution can be the ability to see the reflections of both the top and bottom of a layer as two separate events in the seismic section. It can be shown that for this to happen, the thickness of the layer must exceed $\lambda/2$, where λ is the seismic wavelength at the given interval. Use the Table 1 to compute the resolution limit in meters for 1000 meters depth, and for 4000 meters depth.

Depth[m]	P-wave velocity [m/s]	Dominant frequency [Hz]
500	2000.0	50.0
1000	2300.0	45.0
2000	3000.0	25.0
3000	3500.0	18.5
4000	3000.0	12.5

Table 1: Table for Problem 2d.

Problem 2
40% Seismic methods

a) 12% Draw a figure with two horizontal layers. Assume that we have a seismic source and receivers at the surface of the upper layer, and draw the refracted wave associated with the interface between the two layers.

i) What are the conditions (mention two) that need to be fulfilled for us to measure this refracted wave?

ii) Use Snell's law ($p = \sin\theta_1/v_1 = \sin\theta_2/v_2$) to find an expression for the critical angle of refraction when v_1 and v_2 are the velocities of the two layers.

iii) Assume that the thickness of the upper layer is h and show that the traveltime of the refracted wave can be written as

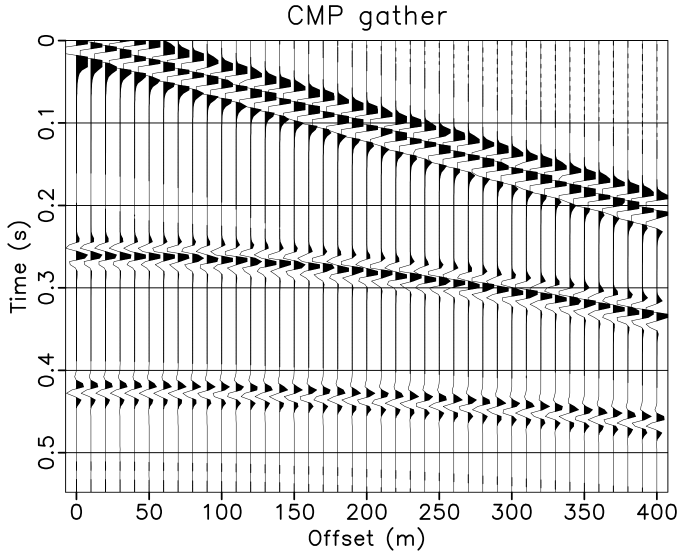
$$T(x) = \frac{x}{v_2} + \frac{2h\sqrt{v_2^2 - v_1^2}}{v_1 v_2}, \tag{2}$$

where x is the distance between the source and the receiver.

b) 12% Figure 1 shows a seismogram acquired over a layered earth. A selection of picked traveltimes are shown numerically in the table to to the right.

i) Compute the velocity V_1, and the thickness Z_1 of the upper layer.

ii) Compute the rms-velocity down to the second reflector ($V_{RMS,2}$).



x[m]	ref.1 [ms]	ref.2 [ms]
0	263.1	429.8
100	268.3	432.4
200	283.4	440.1
300	306.8	452.7
400	337.0	469.8

Figure 1: A seismogram acquired over a layered earth. Here ref. 1, means reflection nr. 1 and "ref. 2", reflection nr. 2, and x means source-receiver offset. Note that the traveltimes are given in miliseconds.

iii) Compute the velocity (V_2) and thickness (Z_2) of the second layer.

c) 10% Figure 2 shows a screenshot from a seismic processing software.

i) What seismic process is shown in Figure 2?

ii) What sort of plot is shown in the left window, and what sort of gather is shown in the second window from the left?

iii) What do the white and black curves in the left window represent?

iv) What sort of correction is applied to the middle gather ?

v) Finally, what does the "Stack" in the rightmost window mean, and how is it computed?

d) 6% Compute the amplitudes A_1, and A_2 in Figure 3. Here we assume normal incidence, and we also assume plane waves such that geometrical spreading can be neglected.

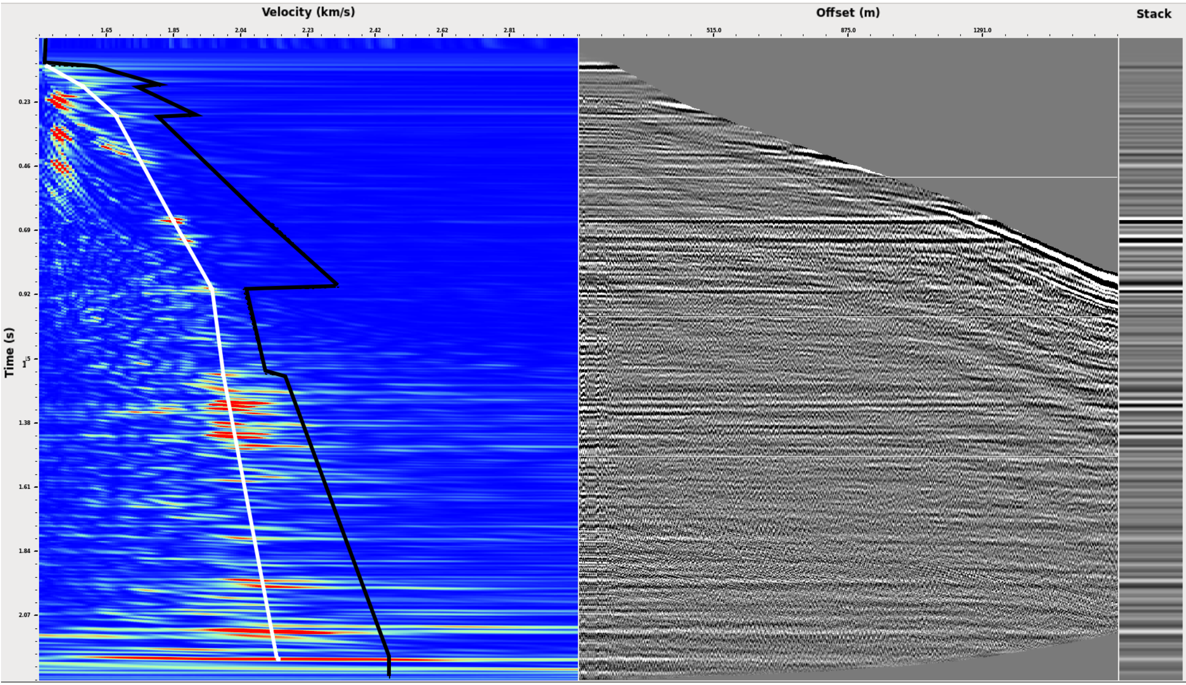


Figure 2:

Problem 3
30% Gravity and Electric methods

a) 5% The international gravitational formula is given as

$$g_\phi = 9.780327(1 + 0.0053024\sin^2\phi - 0.0000058\sin^2 2\phi) \qquad (3)$$

Explain the meaning of the symbols in the equation, and use the formula to compute gravity at the equator and at the poles.

b) 10% What corrections to the gravity anomaly are included in the simple Bouguer anomaly?

c) 10% For which geological situations are the following forms of resistivity surveying most useful:

i) VES
ii) CST
iii) VES + CST

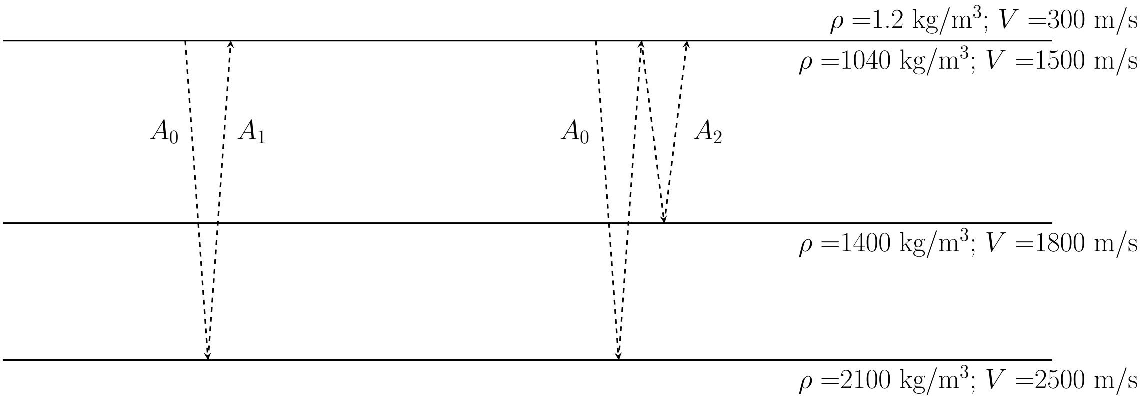


Figure 3: Oppgave 2d

d) 5% The apparent resistivity to a general 4 electrode array (Figure 4) can be written as

$$\rho_a = \frac{2\pi(V_C - V_D)}{I\left\{\left(\frac{1}{r_A} - \frac{1}{r_B}\right) - \left(\frac{1}{R_A} - \frac{1}{R_B}\right)\right\}} \tag{4}$$

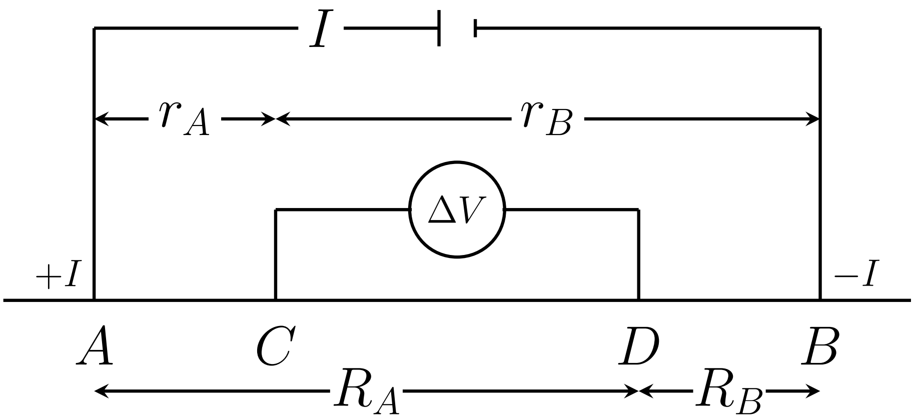


Figure 4: A general 4 electrode array used in resistivity surveys

Assume now that the distance between A and C, C and D, and D and B is equal to a and show that the apparent resistivity can the be written as:

$$\rho_a = \frac{2\pi\left(V_C - V_D\right)}{I}a \tag{5}$$

Formulas that can be useful:

$$f_{Nyq} = \frac{1}{2\Delta t}$$

$$V_P = \sqrt{\frac{\lambda + 2\mu}{\rho}} = \sqrt{\frac{k + \frac{4}{3}\mu}{\rho}}$$

$$V_S = \sqrt{\frac{\mu}{\rho}}$$

$$\sin\theta_k = \frac{V_1}{V_2}$$

$$R_{ij} = \frac{\rho_j v_j - \rho_i v_i}{\rho_j v_j + \rho_i v_i}$$

$$T_{ij} = 1 - R_{ij}$$

$$t^2 = t_0^2 + \frac{x^2}{v_{RMS}^2}$$

$$V_{rms,n} = \left[\frac{\sum_{i=1}^{n} V_i^2 \Delta t_i}{\sum_{i=1}^{n} \Delta t_i}\right]^{1/2}$$

$$V_n = \left[\frac{V_{rms,n}^2 t_n - V_{rms,n-1}^2 t_{n-1}}{t_n - t_{n-1}}\right]$$

$$\sin^2\theta + \cos^2\theta = 1$$

$$\lambda = \frac{v}{f}$$

$$\omega = 2\pi f$$