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FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET110 Geophysics and Well Logging

DATE: May 23rd 2019

TIME: 4 hours

AID: One handwritten A4-page with notes. Approved calculator

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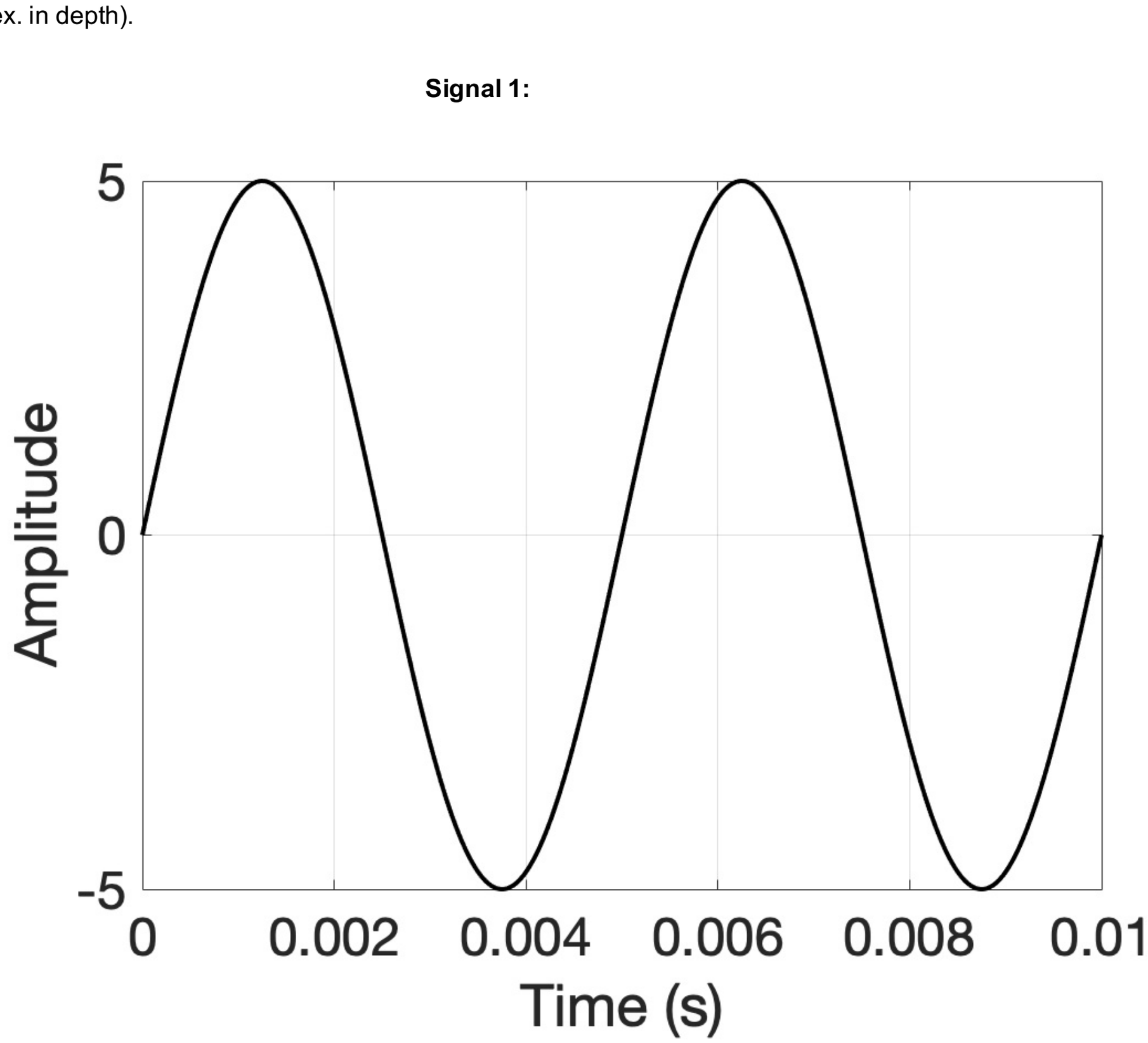
1 Sampling and Aliasing

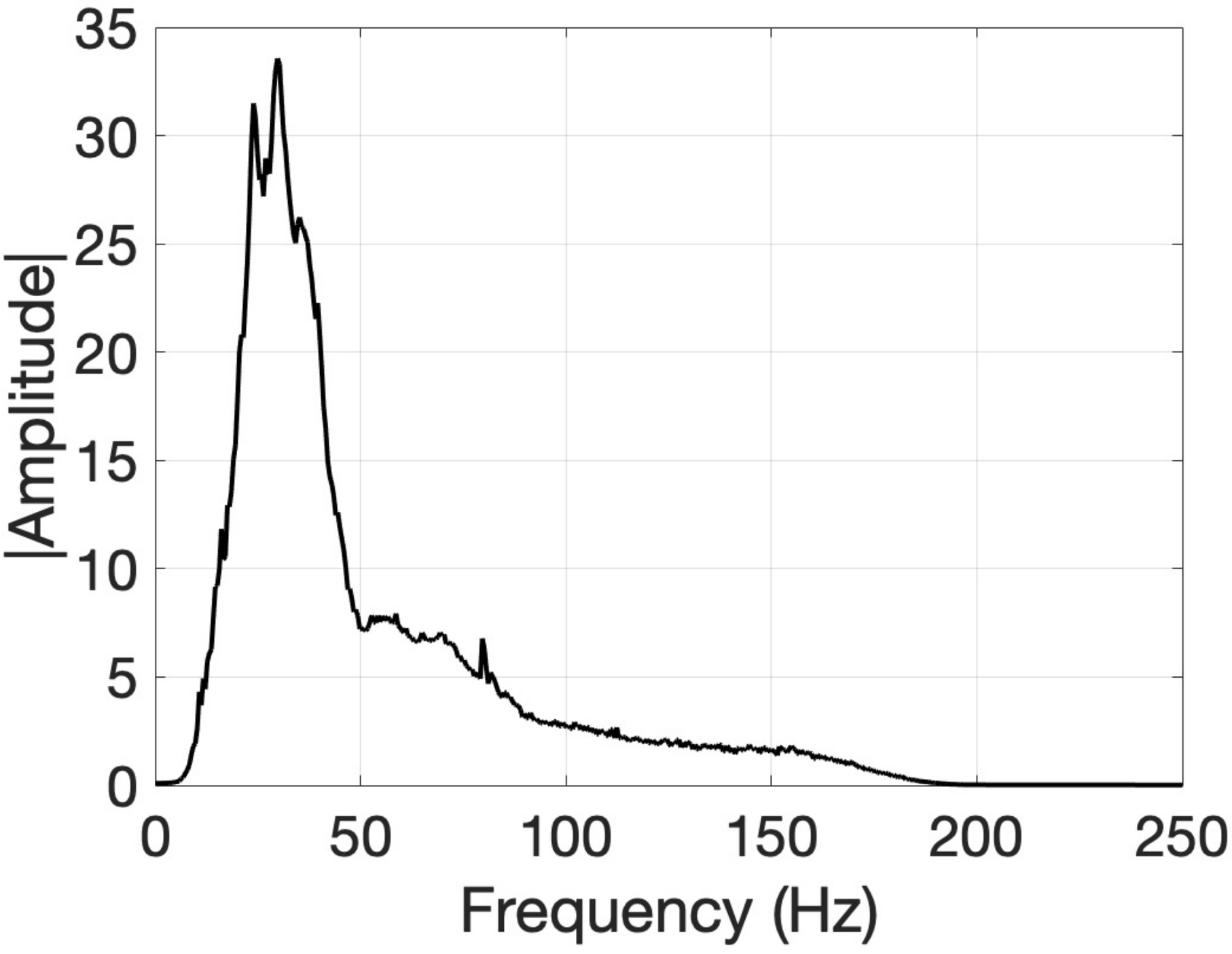
a. What is the Shannon/Nyquist criteria, that is, how should an analog (continuous) signal be sampled in order to be possible to properly reconstruct it from the samples?

b. For each of the signals below determine the largest possible sampling interval such as to avoid aliasing. Note: Be careful with the units, some signals are temporal recordings (i.e in time), others are spatial recordings (ex. in depth).

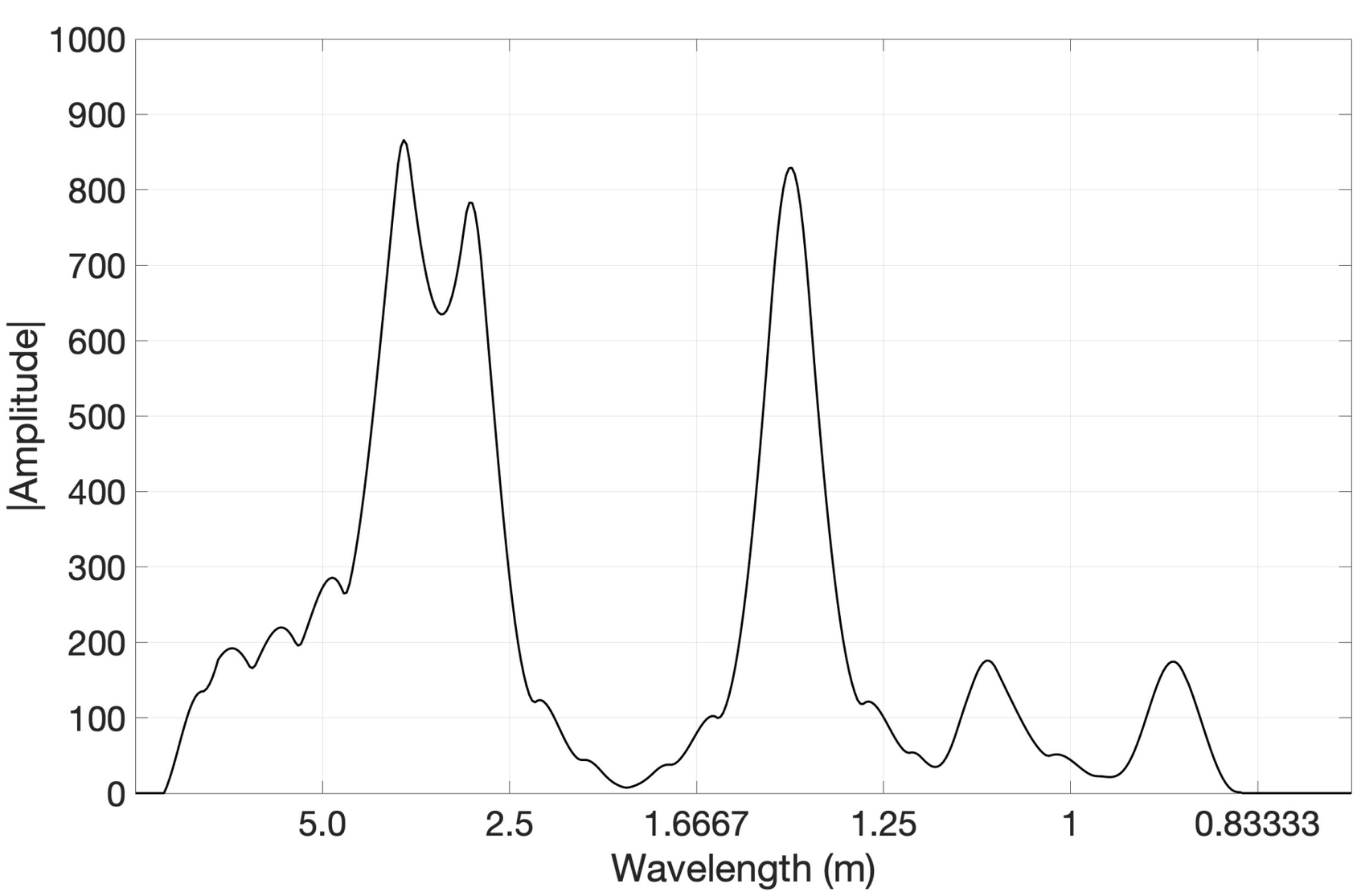
Signal 1:



Signal 2:


|Amplitude|
0
5
10
15
20
25
30
35
0
50
100
150
200
250
Frequency (Hz)

Signal 3:


|Amplitude|
0
100
200
300
400
500
600
700
800
900
1000
5.0
2.5
1.6667
1.25
1
0.83333
Wavelength (m)

Fill in your answer here

Format

Words: 0

Maximum marks: 10

2 Elastic moduli and Reflection of seismic waves

The table below gives the densities and seismic P- and S-wave velocities at various depths in the Earth.

Densities and seismic velocities in the Earth

Depth $[km]$	Densities $[kg/m^3]$	P-wave $[km/s]$	S-waves $[km/s]$
100	3380	8.05	4.45
500	3850	9.65	5.22
1000	4580	11.46	6.38
2000	5120	12.82	6.92
2890	5560	13.72	7.27
2900	9900	8.07	0
4000	11320	9.51	0
5000	12120	10.30	0
5500	12920	11.14	3.58
6470	13090	11.26	3.67

a. From these quantitites calculate the Bulk modulus (k), Shear modulus (μ) and Poisson's ratio (ν) at each depth.

b. Describe in your own words the information that these data give about the interior of the Earth.

c. Determine the normal incidence reflection coefficient at an interface between 2890 and 2900 kilometers.

d. If a P-wave impinges (hits) the interface at 2890 km with an angle of 30 degrees with respect to the normal, what is the angle of refraction as the wave transmits through the interface?

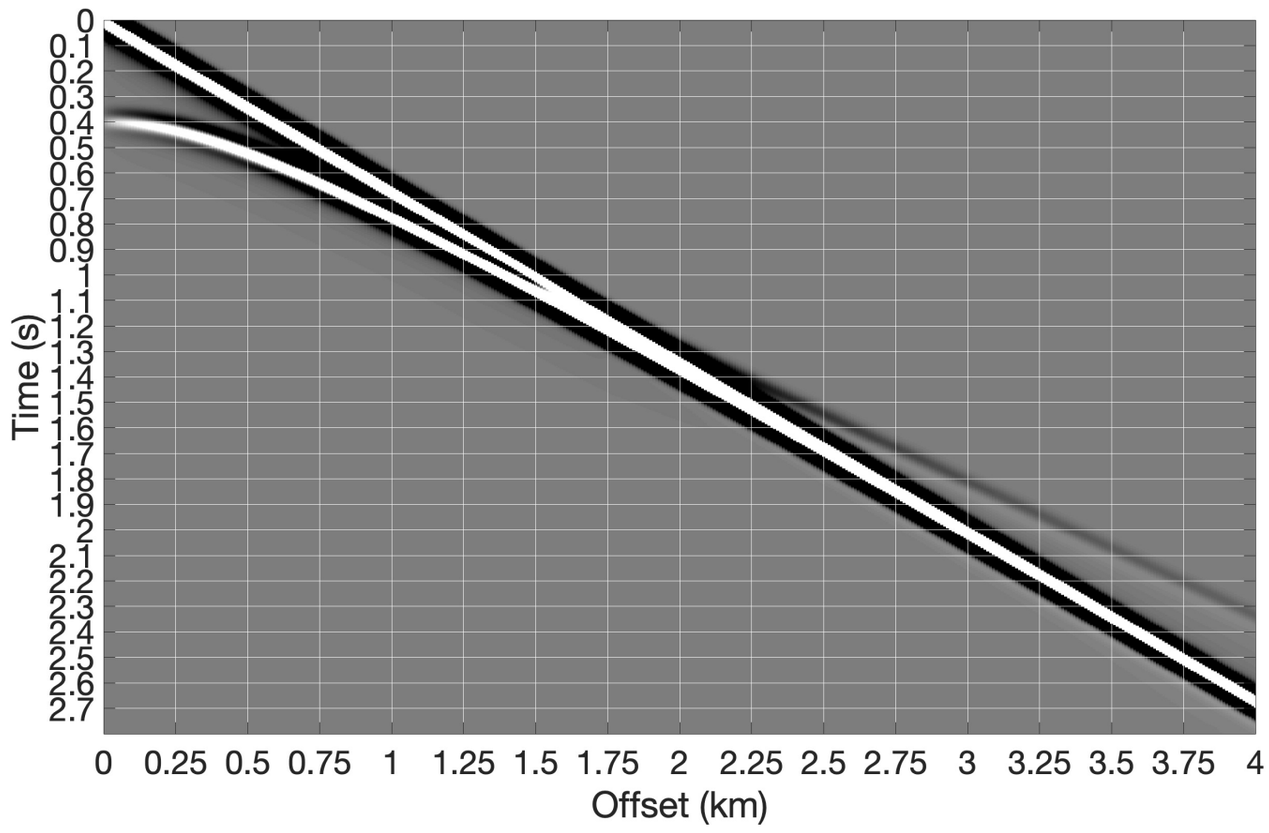
Fill in your answer here

Format | B I U x_2 x^2 | I_x | Ω | ∑ | ABC

Words: 0

Maximum marks: 10

3 Refraction seismic



The figure shows a seismogram acquired over a horizontally layered earth.

a. From the first arrivals determine how many layers are detected by these measurements.
b. Determine the seismic velocities at these layers.
c. Determine the thickness of the topmost layer.

Fill in your answer here

Format | B I U x_2 x^2 I_x | ABC

Words: 0

Maximum marks: 10

4 Seismic velocities

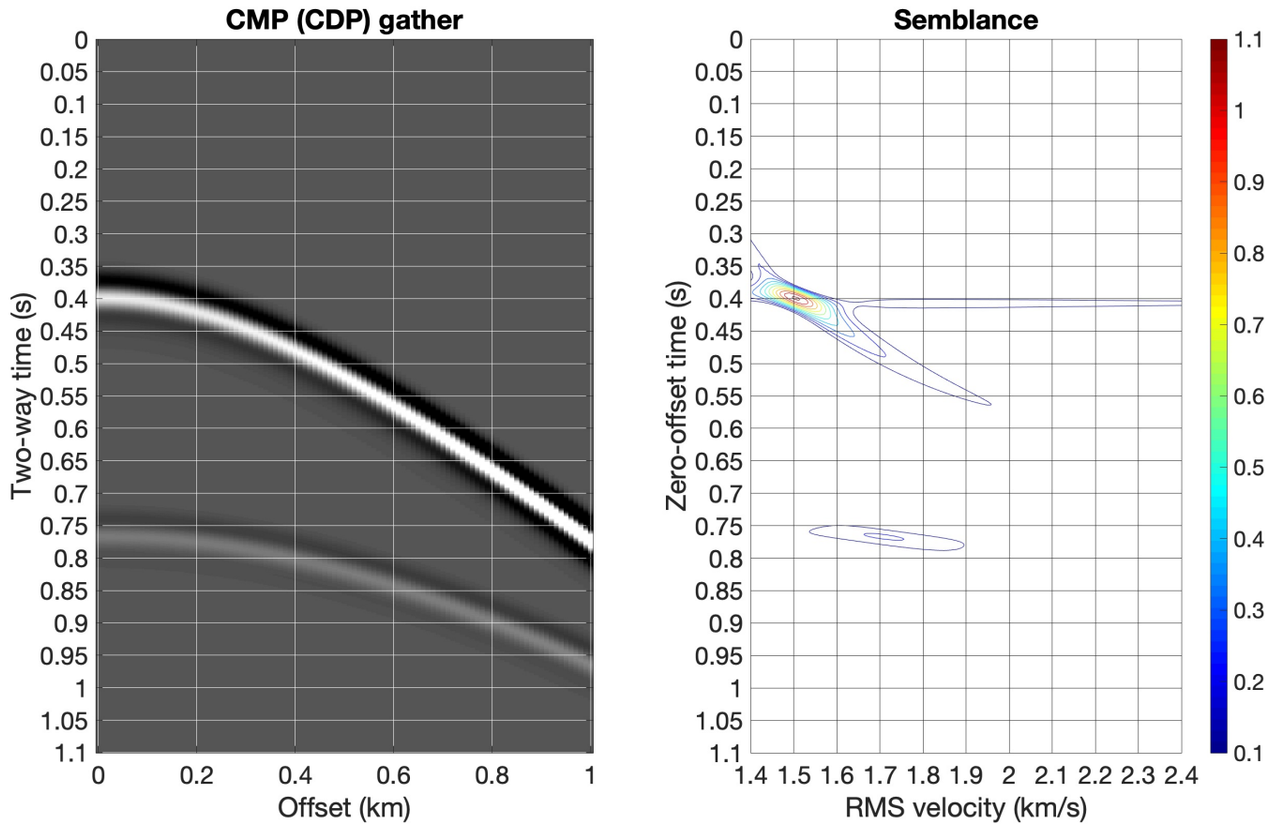
Consider a rock with P- and S-wave velocities Vp, Vs. Assume that when the rock is a water saturated reservoir clastics, the ratio $Vp/Vs \approx 2$. But when the rock is gas saturated, roughly what would you expect Vp/Vs to be?

Select one alternative:

- Lower
- The same
- Higher

Maximum marks: 6

5 Reflection Seismic



The figure shows a CMP (or CDP) gather and an associated Semblance map.

a. Use the data to determine the RMS Velocities and zero-offset traveltimes for the two reflections seen in the CMP gather.

b. From the RMS velocties and zero-offset traveltimes calculate the interval velocities V_1 and V_2, and the thicknesses Z_1 and Z_2 for the top two layers.

Fill in your answer here

Format

Words: 0

Maximum marks: 10

6 # Gravity 1

a. Mention the 3 reasons gravity varies as a function of Latitude. Include in your answer whether each of the effects contribute to increase of decrease gravity around the Equator.

b. Name 2 different gravity corrections used in gravity reduction and explain what they are used for.

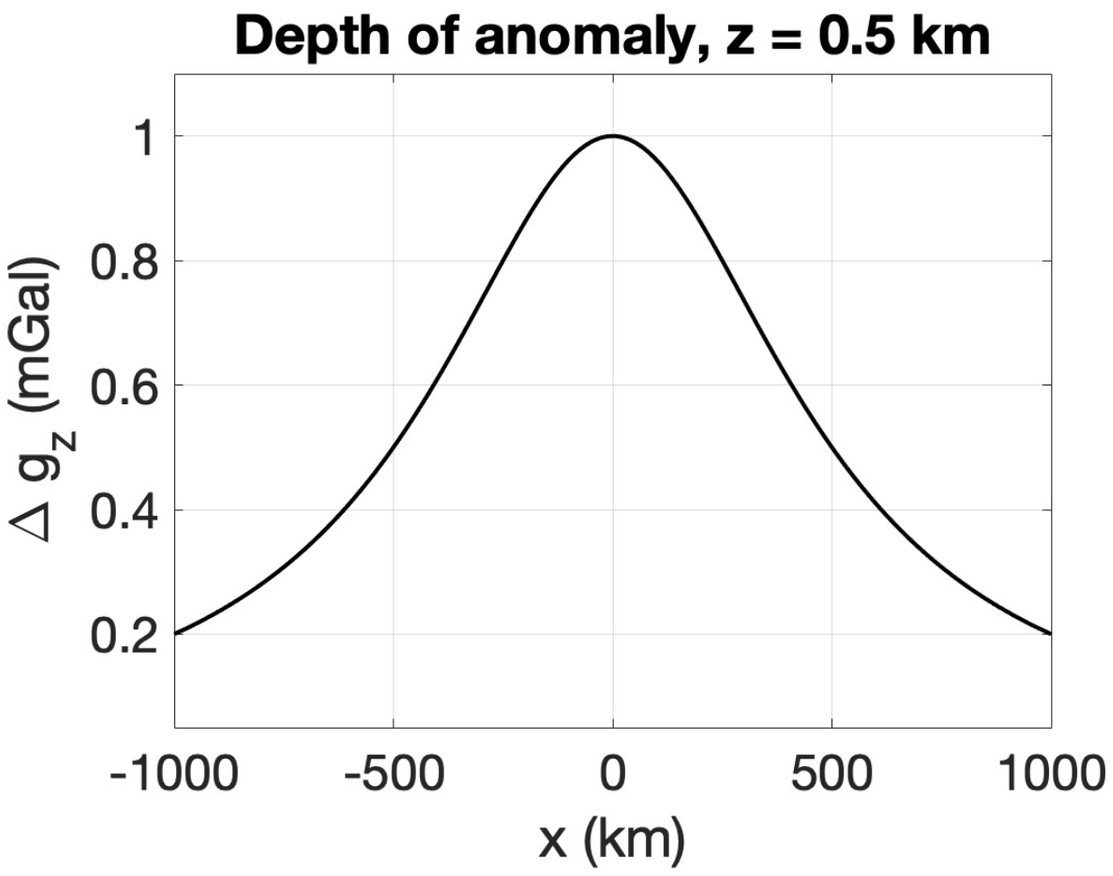
Fill in your answer here

Format | B I U x_2 x^2 I_x | Ω | ∑ | ABC

Words: 0

Maximum marks: 8

7 # Gravity 2



The Figure shows a Bougher anomaly gravity profile. Seismic data along the same profile (not shown here) indicates that the source of the bell shaped anomaly in the Figure is an object approximately circular in cross section and at a depth of 500 m. However, since the measurements are done along a profile, it is not possible to know from the seismic if the object is a sphere or a cylinder extending perpendicular to the profile.

Determine using the gravity anomaly data if the source of the anomaly is a sphere or a cylinder. Justify your answer and show your calculations.

Fill in your answer here

Format | B I U x_2 x^2 I_x | Ω | ∑ | ABC

Words: 0

Maximum marks: 10

8

Archie's law and Resistivity logs

Read through carefully. Identify **correct** statements.

Which factors determine electrical resistivity of porous formations?
Select zero, one or more alternatives

- 1. Pore volume fraction
- 2. Oil / water saturation
- 3. Tortuosity
- 4. Cementation exponent
- 5. Presence of clay bound water
- 6. The salinity of the brine in the solution
- 7. The temperature

Which statements are correct?
Select zero, one or more alternatives

- 1. Archies law relate resistivity to clay content and mineralogy
- 2. Archies law is used to calculate the oil/water saturation from resistivity and porosity measurements.
- 3. Archie law is used to calculate the oil/water saturation using the formation factor and the resistivity measurements.

Which statements are correct?
Select zero, one or more alternatives

- 1. The formation factor is related to the electrical conductance of the porous media
- 2. The presence of shales and saline brines affect the resistivity of the formation
- 3. The cementation exponent is linked to the formation factor: Higher cementation exponent --> higher formation factor
- 4. Once a, m, n are known then the hydrocarbon saturation may be calculated from resistivity and porosity logs

Maximum marks: 13

9

Gamma ray log

Gamma rays principles

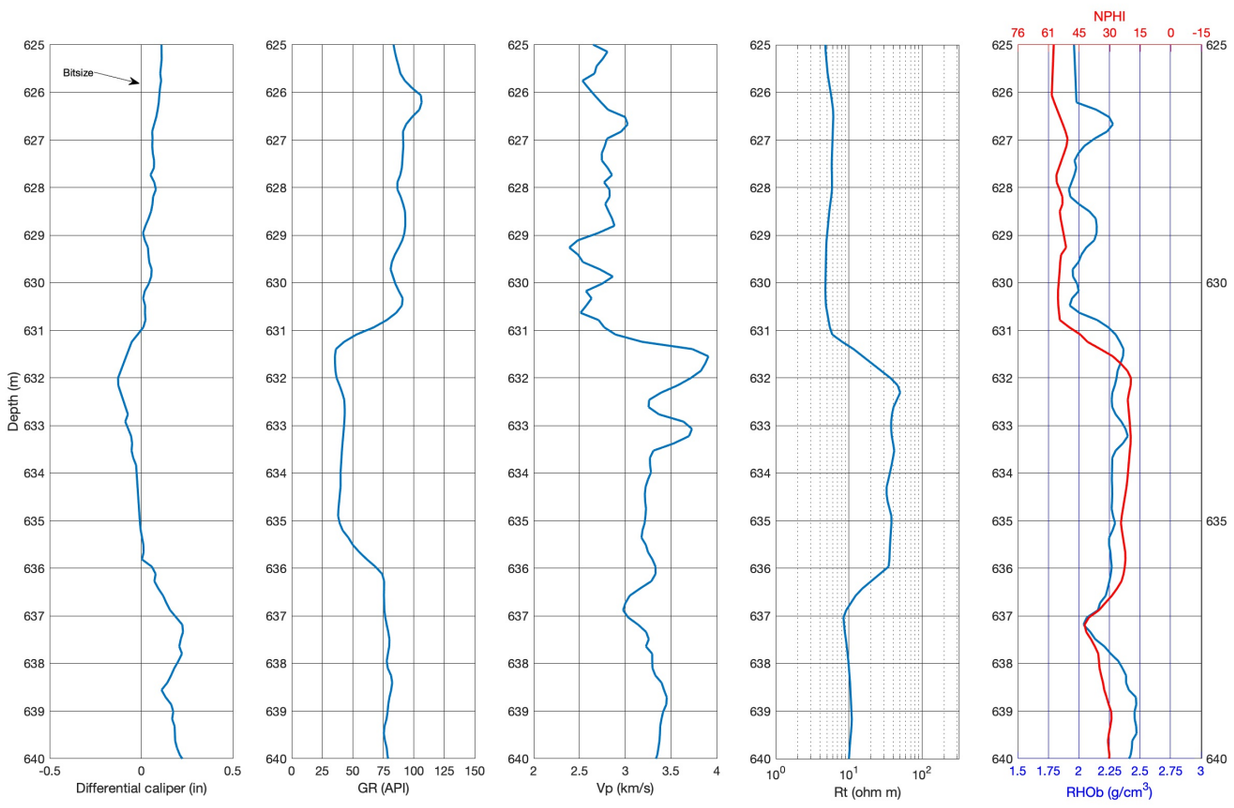
Select the alternative(s) that are true:

- 1. The Gamma Ray log is a measurement of the formation's natural radioactivity
- 2. Gamma ray emission is produced by three radioactive series found in the Earth's crust.
- 3. Gamma rays passing through rocks are slowed and absorbed at a rate which depends on the hydrogen index (HI).
- 4. Pure sands, limestones and dolomites produce generally low radioactivity compared to shales.
- 5. A major use of the tool is to identify marker beds and thus allow well-to-well correlation.
- 6. Gamma ray logs allow lithology and mineralogy to be uniquely defined.

Maximum marks: 4

10

Log interpretation



a. Using the differential caliper log (Caliper - Bitsize), identify mudcake formations, and potential cavings and wash outs . Justify your answer.

b. Identify permeable zones, if any. Justify your answer.

c. What lithology or lithologies do you associate with the interval between 631 and 636 m. What information are you using as a basis for your classification?

d. Are there any indications of the presence of hydrocarbons in the logs? Justify your answer.

e. Determine the porosities at the depths of 632 m and 638 m, and using both the density, and the sonic logs. Take the necessary values for your calculations from the tables below. Note: You should provide 4 values in total, one derived from sonic and one derived from density for each depth.

Density and seismic velocities of some rock minerals and pore fluids

Mineral/ Fluid	**Density (g/cm^3)**	**Seismic velocity (km/s)**
Quartz	2.65	6.05
Mica (clay mineral)	2.82	5.81
Calcite	2.71	6.54

Water (Brine)	1.146	1.585
Water/HC mix	0.6	1.055

f. Determine the water saturation at a depth of 632 m. Assume a tortuosity factor of 0.81, a cementation factor of 2.8 and a resistivity of the porewater (R_w) of 0.08 ohmm. For the porosity, use a value of 18%. Show your calculations.

g. Calculate the volume of shale (V_{sh}) at the depths of 630 m and 632 m. Show your calculations, and what values you used for the sand and shale lines.

Fill in your answer here

Format | B I U x_2 x^2 I_x | Ω | ∑ | ABC

Words: 0

Maximum marks: 19

Formula sheet

Formulas that can be useful:

Frequency (f) and Wavenumber (k) relations:

$$f = \frac{1}{T}$$

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

$$k = 1/\lambda$$

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

$$k_{Nyq} = \frac{1}{2\Delta x}$$

Seismic velocities:

$$v_p = \sqrt{\frac{k+\frac{4}{3}\mu}{\rho}}$$

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

Possion ratio:

$$\nu = \frac{1}{2}\frac{v_p^2 - 2v_s^2}{v_p^2 - v_s^2}$$

Normal incidence reflection coefficient:

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

Refraction traveltime equations:

$$t_n(x) = \frac{x}{v_n} + 2\sum_{i=1}^{n-1}\frac{h_i \cos\theta_{i,n}}{v_i}$$

Reflection traveltime equations:

$$t_0 = 2\sum_{i=0}^{n}\frac{h_i}{v_i}$$

$$t_n^2(x) = t_{0,n}^2 + \frac{x^2}{v_{rms,n}^2}$$

Dix Formula:

$$v_n^2 = \frac{v_{rms,n}^2 t_{0,n} - v_{rms,n-1}^2 t_{0,n-1}}{t_{0,n} - t_{0,n-1}}$$

$$h_n = v_n\left(\frac{t_{0,n} - t_{0,n-1}}{2}\right)$$

Gravity anomalies of simple bodies (vertical component):

Sphere:

$$\Delta g_z = \frac{Gmz}{r^3}$$

Cylinder:

$$\Delta g_z = \frac{2Gmz}{r^2}$$

Slab of thickness h:

$$\Delta g_z = 2\pi G\rho h$$

$$G = 6.67408e{-}11$$

Wyllie's time-average formula:

$$\frac{1}{V} = \frac{1}{V_{ma}}(1-\phi) + \frac{1}{V_{fl}}\phi$$

Bulk density formula:

$$\rho_b = \rho_{ma}(1-\phi) + \rho_{fl}\phi$$

Archie's law:

$$F = \frac{a}{\phi^m}$$

$${S_w}^2 = \frac{R_o}{R_t} = \frac{FR_w}{R_t}$$

Vshale:

$$V_{sh} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$$