Final Exam - tentative solution

(1) Signal 1

$T = 0.5\,s \qquad f = \frac{1}{T} = 2\,Hz \qquad \phi = -45° = -\pi/4$ radians

$A = 6$

$$s_1(t) = 6 \cdot \cos(2\pi \cdot 2 \cdot t - \pi/4)$$

Signal 2

$T \Rightarrow$ time between peaks or troughs along vertical lines.

$\lambda \Rightarrow$ distance between peaks along horizontal lines.

$T = 0.1\,s$

$\lambda = 50\,m$

$$v = \frac{\lambda}{T} = 500\,m/s$$

$A = 10$

$$s_2(x,t) = 10 \cos\left[\frac{2\pi}{50}(x - 500 \cdot t)\right]$$

2. Taking the maximum frequency of the signal to be 80 Hz. We need to choose a sampling interval such that the Nyquist frequency is higher than 80 Hz.

$$f_{Nyq} = \frac{1}{2\Delta t} > 80 \qquad \Delta t < \frac{1}{160} \Rightarrow \Delta t < 6.25\,ms$$

(3.) 1. The dominant frequency of the noise is close to 0 Hz, as seen from the spike on the spectrum.

2. You will need a high pass filter with a low cut of circa 2 Hz.

(4.) Which factors determine electrical resistivity of porous formations:

All alternatives are correct.

Which statements are correct:

2 and 3

Which statements are correct:

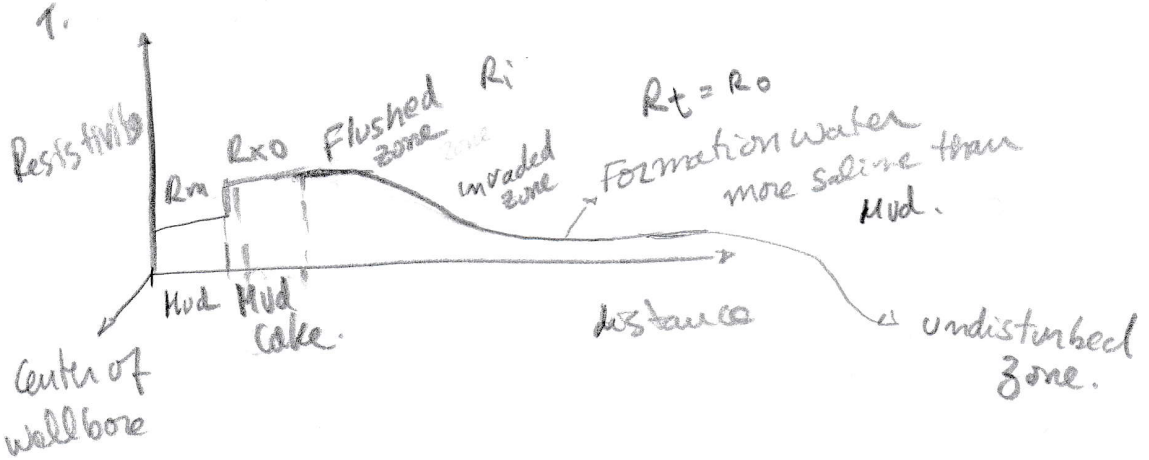
All correct.

(5) 1. Laterologs, Induction and propagation

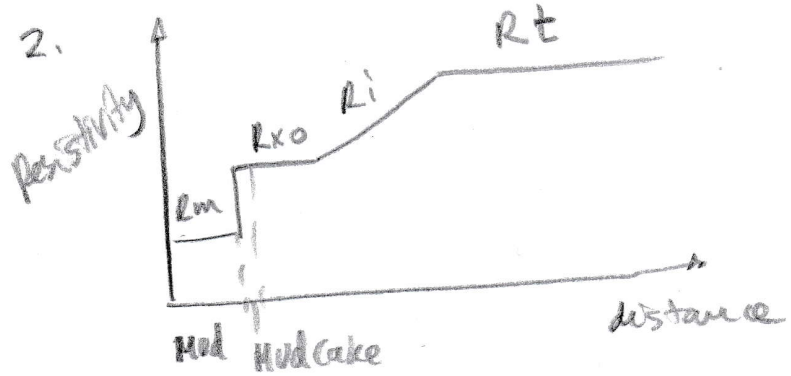
2. Induction and propagation

3. Propagation methods only.

6. 1.



2.



7.

Calcite

$K = 110 \times 10^9$ $\mu = 35 \times 10^9$ $\rho = 2710\ kg/m^3$

Water

$K = 2.2 \times 10^9$ $\mu = 0$ $\rho = 1000\ kg/m^3$

1. $V_P = \sqrt{\frac{K + 4/3\,\mu}{\rho}}$

Calcite

$V = 7603\ m/s$

$\frac{1}{V} = 40.1\ \mu s/feet$

Water

$V = 1483\ m/s$

$\frac{1}{V} = 205.5\ \mu s/feet$

(7.) cont.

$$V = \frac{0.08\ m}{16e^{-6}} = 5000\ m/s$$

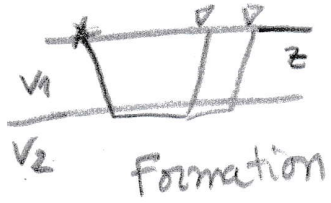
2. $$\phi = \frac{\frac{1}{V} - \frac{1}{V_{ma}}}{\frac{1}{V_{fl}} - \frac{1}{V_{ma}}}$$

$$\phi = \frac{\frac{1}{5000} - \frac{1}{7603}}{\frac{1}{1483} - \frac{1}{7603}} = \underline{\underline{12.6\ \%}}$$

(8.) Sonic logging as shown in the schematic figure uses the traveltimes of the first arrivals to calculate the seismic velocities of the formation near the wellbore.

The traveltimes of first arrivals are given by the refraction traveltime equation:

$$t(x) = \frac{1}{V_2} \cdot x + \frac{2z\cos\theta_c}{V_1}$$



The change in traveltime (Dt) divided by the distance between the receivers is equal $\frac{1}{V_2}$, the slowness of the formation.

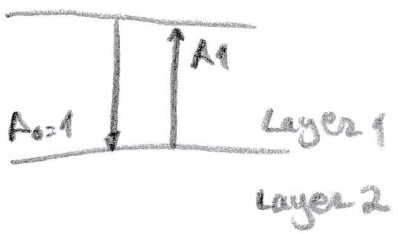
(10) (5)

$$R_{ij} = \frac{z_j - z_i}{z_j + z_i}$$

1. $R_{12} = \dfrac{2700 \cdot 2250 - 2200 \cdot 2150}{2700 \cdot 2250 + 2200 \cdot 2150} = 0.1245$

2. $R_{23} = -0.1245$

3.

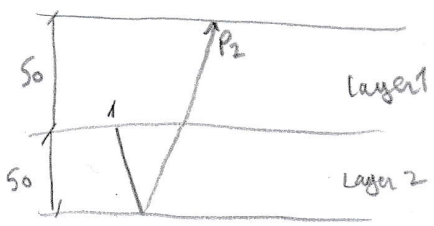


$A_1 = R_{12} \cdot 1 = 0.1245$

4. With geometrical divergence:

$$A_1 = \frac{A_0 \cdot R_{1,2}}{d} = \frac{0.1245}{50} = 0.0025$$

5.



$P_2 = 1 \cdot T_{1,2} \cdot R_{2,3} \cdot T_{2,1} =$

$= 0.8755 \cdot -0.1245 \cdot 1.1245 = -0.1226$

6. $P_2 = \dfrac{-0.1226}{50+50+50} = -0.000817$

7. $V^2_{RMS_{1m}} = \dfrac{\sum_{i=1}^{m} \frac{V_i \cdot h_i}{h_i}}{\sum_{i=1}^{m} \frac{h_i}{V_i}}$

$V_{RMS,12} = \sqrt{\dfrac{(2200+2700) \cdot 50}{\frac{50}{2200} + \frac{50}{2700}}} = 2437.2$ m/s

11.

a. Reflection 1

$V_{RMS,1} = V_1 = 1500$ m/s

$t_{0,1} = 0.4$ s

Reflection 2

$V_{RMS,2} = 1700$ m/s

$t_{0,2} = 0.77$ s

b. Using the Dix formula:

$$V_2 = \sqrt{\frac{V_{RMS,2}^2 \cdot t_{0,2} - V_{RMS,1}^2 \cdot t_{0,1}}{t_{0,2} - t_{0,1}}} =$$

$$= \sqrt{\frac{1700^2 \cdot 0.77 - 1500^2 \cdot 0.4}{0.77 - 0.4}} = 1892.6 \text{ m/s}$$

$$z_1 = \frac{V_1 \cdot t_{0,1}}{2} = \frac{1500 \cdot 0.4}{2} = 300 \text{ m}$$

$$z_2 = \frac{V_2 \cdot (t_{0,2} - t_{0,1})}{2} = 350.1 \text{ m}$$

15. 1. $GR^{sand} = 60$ (Sand Line)

$GR^{shale} = 180$ (Shale Line) ignoring spikes

$GR \approx 75$ (Base of Grid FM)

$$V_{sh} = \frac{75 - 60}{180 - 60} = 0.1250 \quad \text{or } 12.5\%.$$

2. The sonic log gives ca 105 µs/feet as the smallest slowness. This corresponds to a velocity of

$$V_{max} = \frac{0.3048}{105 \times 10^{-6}} = 2900 \text{ m/s}$$

3. The Bulk density reads ca. 2.1 g/cm³ on average:

The porosity can be calculated from the densities according to:

$$\varphi = \frac{\rho_B - \rho_{ma}}{\rho_{fl} - \rho_{ma}} = \frac{2.1 - 2.65}{1.04 - 2.65} = \underline{0.3416}$$

4. Formation factor:

$$F = \frac{a}{\varphi^m} = \frac{0.62}{0.34^{2.15}} = 6.3$$

Humble formula
$a = 0.62$
$m = 2.15$

$\underline{R_w}$: ↙ From the resistivity log (deep)

$R_0 = 0.3 : F \cdot R_w$

$$R_w = \frac{R_0}{F} = \frac{0.3}{6.3} = 0.0476$$

(15) cont

5. The minimum slowness along the log is ca 70 μs/feet.

This corresponds to a velocity of $V = \frac{0.3048}{70 \times 10^{-6}} = 4354$ m/s.

Such high velocities are typical of carbonates or evaporites.

However, highly compacted and cemented sandstones and shales can also exhibit such high velocities.

6. Hydrocarbons may be present between 1900 and 2000 m MD.

The main indication is the high resistivities. But a slight crossover along this interval could also indicate high hydrogen index.

On the other hand, the gamma ray is very high, which is not typical for reservoir lithologies, except in the case of high potassium content.

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Multiple choice problems

May 20, 2020

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

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

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

- [x] 1. Archies law relate resistivity to clay content and mineralogy
- [x] 2. Archies law is used to calculate the oil/water saturation from resistivity and porosity measurements
- [x] 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

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

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9 **Principles of reflected waves**

Select the alternatives which are **true:**
Select one or more alternatives

- [ ] Normal moveout is the time taken for the reflections to arrive at the receiver after normal incidence reflection
- [ ] The shape of the traveltime for a reflection from a horizontal interface measured at a flat surface is hyperbolic ✓
- [ ] The normal moveout of reflected waves depend on the zero-offset traveltime, source-receiver offset and the root mean square velocity of the stack of layers above the reflector ✓
- [ ] Snells law can be used to determine the amplitude of the reflected and transmitted waves through the medium
- [ ] A negative reflection coefficient is a consequence of a wave transmitting into a softer medium. ✓
- [ ] Hydrocarbon production leads to changes in amplitudes of reflected seismic waves ✓
- [ ] Reflection traveltimes vary linearly with the source-receiver offsets
- [ ] Waves reflect at boundaries marking a change in the acoustic impedance of the medium ✓
- [ ] Hydrocarbon production leads to changes in the traveltimes of seismic waves ✓

12 **Principles of Gravity and Magnetics**

Select the alternatives which are **true** regarding gravity measurements:
Select one or more alternatives:

- [ ] The free-air gravity anomaly is corrected for the effect of variations of gravity with latitude ✓
- [ ] Due to the centripetal acceleration, the gravity decreases when moving from the Equator to the Poles.
- [ ] Due to the centripetal acceleration, the gravity increases when moving from the Equator to the Poles. ✓
- [ ] The Bougher correction is used to remove the effect of different elevation from the gravity measurements
- [ ] Standard gravimeters are levelled and therefore only measure the "vertical" component of gravity ✓

Select the alternatives which are **true**:
Select one or more alternatives

- [ ] The Earth's Magnetic field is affected by electromagnetic activity in the atmosphere ✓
- [ ] Magnetic anomalies depend on the magnetic susceptibility and remanent magnetisation of the materials in the subsurface ✓
- [ ] The Magnetic field of the Earth is due to a giant magnet at the center of the Earth
- [ ] Remanent magnetism is a measure of how much a material gets magnetised when in the presence of an external field
- [ ] Compared to gravity the strength and direction of the magnetic field varies much more strongly from Equator to the Poles. ✓
- [ ] The Magnetic field can be approximately modelled by a dipole placed at the center of the Earth ✓

Spectral Gamma Ray can be used to identify the relative proportion of potassium, thorium and uranium in the radioactive minerals:
Select one or more alternatives:

- [ ] True ✔
- [ ] False

Caliper log can be used to measure the diameter of the well with depth:
Select one or more alternatives:

- [ ] True ✔
- [ ] False

The Liquid Junction potential is more important to the SP-log result than the shale potential:
Select one or more alternatives:

- [ ] True
- [ ] False ✔

Laterolog resistivity tools can be used when oil based drilling muds are used:
Select one or more alternatives:

- [ ] True
- [ ] False ✔

The Neutron log works by bombarding the adjacent formation with gamma rays:
Select one or more alternatives:

- [ ] True
- [ ] False ✔

The hydrogen index (HI) is only controlled by the presence of hydrocarbons:
Select one or more alternatives:

- [ ] True
- [ ] False ✔

High energy neutrons interact with the electron cloud:
Select one or more alternatives:

- [ ] True
- [ ] False ✔

Mud invasion into the surrounding reservoir matrix affects the near well resistivity reading:
Select one or more alternatives:

- [x] True
- [ ] False