P1 a) Using the formula for the Nyquist frequency:

$f_{Nyq} = \frac{1}{2\Delta t}$, and using the fact that f_{Nyq} must be larger than 275 Hz, which is the maximum frequency seen in Figure 1.

$$\Delta t = \frac{1}{550} = 1.8 \times 10^{-3}\ s = 1.8\ ms$$

b) The main reasons are

(1) Absorption, which has a low pass filtering effect upon the waves. This decreases the bandwidth and also the dominant frequency shifts towards lower frequencies.

(2) Velocities increase with depth due to compaction, cementation.

These two reasons act to increase the wavelength, since wavelength is a function of frequency and phase velocity:

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

The dominant frequency in Figure 1 is around 90 Hz. (2)

This gives $\lambda = \frac{2500}{90} = 27.7$ m.

P1 c) $V_p = \sqrt{\frac{k + 4/3 \mu}{\rho}}$ $V_s = \sqrt{\frac{\mu}{\rho}}$

$$\frac{V_p}{V_s} = \sqrt{\frac{k + 4/3 \mu}{\mu}}.$$

Assuming that k and μ must always be positive, it is impossible for Vs to be larger than Vp.

P1 d) In this problem, there is a piece of information missing, which is the density of the water (1040 kg/m^3).

Symbols:

ρ_f → density of fluid

ρ_s → density of the solid (frame and minerals)

φ → porosity in percent

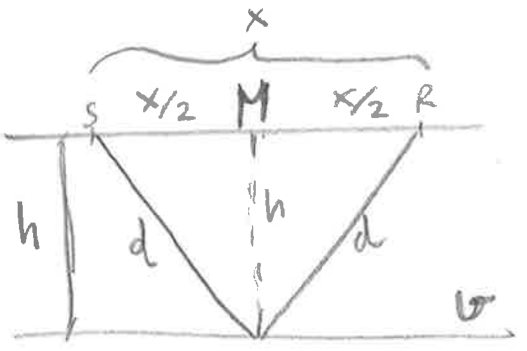
Fully oil saturated case:

$\rho = 700 \times 0.3 + 2600 \times 0.7 = 2030$ kg/m^3

Fully water saturated case:

$\rho = 1040 \times 0.3 + 2600 \times 0.7 = 2132$ kg/m^3

P2 a)



$$T(x) = 2 \cdot \frac{d(x)}{V}$$

$$d(x) = \sqrt{\frac{x^2}{4} + h^2}$$

$$T(x) = \frac{2}{V}\sqrt{h^2 + \frac{x^2}{4}}$$

Rakkeutvikling:

$$T(x) = \frac{2h}{V}\sqrt{1 + \frac{x^2}{4h^2}} \approx \frac{2h}{V}\left(1 + \frac{x^2}{8h^2}\right)$$

NMO correction is used to remove the effect of offset (x) upon the traveltime such that $T(x) = T(0)$.

$$T(x) = T(0) + \Delta T_{NMO}(x)$$

$$\Delta T_{NMO}(x) = \frac{x^2}{4hV} \quad \text{or} \quad \frac{x^2}{2t_0V^2}$$ if we use $t_0 = \frac{2h}{v}$

b) Velocity analysis is used to find the RMS velocities that will best correct for the NMO in the CMP gathers.

These velocities are important for stacking and migration.

Using table:
$x = 2000$ $t = 1.333$

$x = 5000$ $t = 3.333$

$\Delta x = 3000$ $\Delta t = 2$

4

Direct wave slope gives V_1

c) $V_1 = \dfrac{\Delta x}{\Delta t} = \dfrac{3000}{2} = \underline{\underline{1500\,m/s}}$

Slope of ref. 1 gives V_2

$\underline{\underline{V_2 = 2000\ m/s}}$

Slope of ref. 2 gives V_3

$\underline{\underline{V_3 = 3000\ m/s}}$

Using equation (2) we solve for z_1:

$$z_1 = \left(T_2(x) - \frac{X}{V_2}\right) \cdot \frac{V_1}{2\cos\theta_{1,2}}$$

$$\sin\theta_{1,2} = \frac{V_1}{V_2}$$

$$\cos\theta_c = \sqrt{1 - \frac{V_1^2}{V_2^2}}$$

Taking some values from the table:

$$z_1 = \left(2.2646 - \frac{4000}{2000}\right) \cdot \frac{1500}{2 \cdot 0.661} \cong \underline{\underline{300\ m}}$$

Using equation (3) we can solve for z_2:

$$z_2 = \left(T_3(x) - \frac{x}{V_3} - \frac{2z_1\cos\theta_{13}}{V_1}\right) \cdot \frac{V_2}{2\cos\theta_{2,3}}$$

$$\sin\theta_{1,3} = \frac{V_1}{V_3}$$

$$\sin\theta_{2,3} = \frac{V_2}{V_3}$$

Using some values from the table and z_1:

$$z_2 = \left(1.7936 - \frac{3000}{3000} - \frac{600}{1500} \cdot 0.866\right) \cdot \frac{2000}{2 \cdot 0.7453} \cong \underline{\underline{600m}}$$

5

P2 d) $V_p = \sqrt{\frac{k + 4/3\mu}{\rho}}$ $V_s = \sqrt{\frac{\mu}{\rho}}$

Water saturated :

$k = 9 \times 10^9$ $\mu = 4 \times 10^9$ $\rho = 2120\ kg/m^3$

$V_p = \sqrt{\frac{9 \times 10^9 + 4/3\, 4 \times 10^9}{2120}} = 2600.1\ m/s$

$V_s = \sqrt{\frac{4e9}{2120}} = 1373.6\ m/s$

Oil saturated :

$k = 8 \times 10^9$ $\mu = 4 \times 10^9$ $\rho = 2030\ kg/m^3$

$V_p = 2562.8\ m/s$

$V_s = 1403.7\ m/s$

Change in reflection coefficient :

$r_0 = \frac{Z_2 - Z_1}{Z_2 + Z_1}$

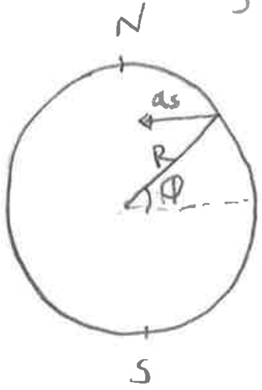
Water saturated :

$r_0^{water} = \frac{2600 \cdot 2120 - 2000 \cdot 2000}{2600 \cdot 2120 + 2000 \cdot 2000} = 0.159$

$r_0^{oil} = \frac{2562.8 \times 2030 - 2000 \cdot 2000}{2562.8 \times 2030 + 2000 \cdot 2000} = 0.130$

$\left.\right\} \ r_0^{oil} - r_0^{water} = \underline{\underline{0.029}}$

P3 a)



Slice through Earth

symbols:

$\frac{d\theta}{dt} = \dot{\theta}$ → rotation speed in radians/s

φ → Latitude

R → Radius of the Earth.

Poles: $\underline{\varphi = 90°}$

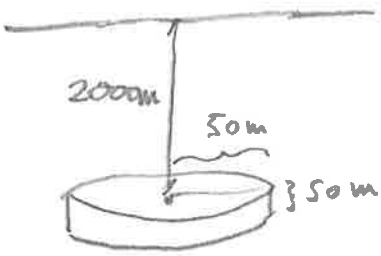
$a_s(90°) = \underline{\underline{0}}\ m/s^2$

Equator $\underline{\varphi = 0°}$

$a_s(0) = 0.034\ m/s^2$

hence the difference is $\underline{\underline{0.034\ m/s^2}}$

b)



Volume $= \pi \cdot r^2 \cdot h =$

$\pi \cdot 50^2 \cdot 50 = 3.927 \times 10^5\ m^3$

Densities and mass:

before compaction:

$\rho_1 = 2190\ kg/m^3$

$m_1 = \rho_1 \cdot V = \rho_1 \cdot \pi \cdot 50^2 \cdot 50 =$

$8.6 \times 10^8\ kg$

After compaction

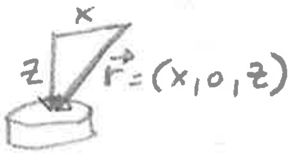
$\rho_2 = 2275\ kg/m^3$

$m_2 = \rho_2 \cdot V = 8.934 \times 10^8\ kg$

Vertical component of gravity:

$$\vec{\Delta g} = (\Delta g_x, \Delta g_y, \underline{\underline{\Delta g_z}}) = \frac{G \cdot m \cdot (x, 0, z)}{|\vec{r}|^3}$$

$$\Delta g_z = \frac{G \cdot m \cdot z}{|r|^3}$$



To avoid having to compute Δg_z (lazy approach)

$$\frac{\Delta g_{z_2}}{\Delta g_{z1}} = \frac{m_2}{m_1} = \frac{\rho_2}{\rho_1} = 1{,}0388$$ or 3.9% increase.

for $x=0$ and $x=2000$ m.

Computing the actual difference:

$$\Delta g_{z1}(x=0) = \frac{6.7 \times 10^{-11} \cdot m_1 \cdot \cancel{z}}{z^{\cancel{3}\,2}} = \frac{6.7 \times 10^{-11} \cdot m_1}{z^2} =$$

$$= 1.4405 \times 10^{-3} \text{ mGal}$$

$$\Delta g_{z1}(x=2000) = \frac{6.7 \times 10^{-11} \cdot m_1 \cdot z}{\sqrt{2000^2 + 2000^2}^{\,3}} = 5.0930 \times 10^{-4} \text{ mGal}$$

$$\Delta g_{z_2}(x=0) = 1{,}4964 \times 10^{-3} \text{ mGal}$$

$$\Delta g_{z_2}(x=2000) = 5.2906 \times 10^{-4} \text{ mGal}$$

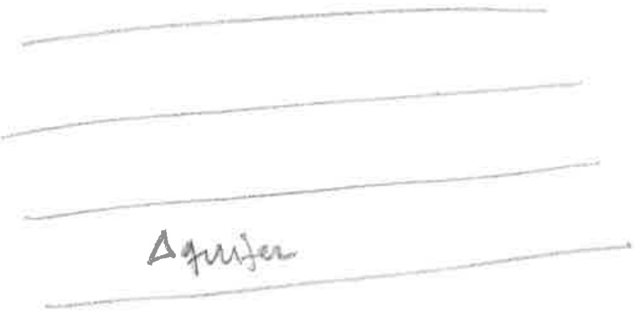
Difference at $x = 0$:

$$\Delta g_{z_2} - \Delta g_{z1} = 5.6 \times 10^{-5} \text{ mGal}$$

Difference at $x = 2000$:

$$\Delta g_{z_2} - \Delta g_{z1} = 1{,}97 \times 10^{-5} \text{ mGal}$$

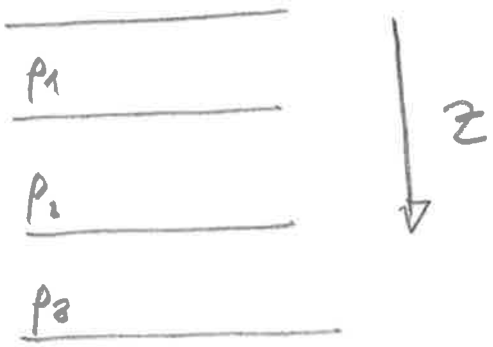
c) Flat region: (Variation is mainly in the Vertical direction)



Best option is to use <u>VES</u>.

d) From the figure there appears to be at least three Layers in the subsurface with different resistivities.

So, this gives:



Ranking from apparent resistivity.

$\rho_2 < \rho_1 < \rho_3$