Homework 1 (EAS 4803: Planetary Sound - SPRING SEMESTER 2020)
Total points: 100
Due 01/17/2020 (Answer Key)

1. [20] The speed of sound in water at is about 1.5 km/sec at the sea level. Based on what you have learned in the class:
a. please find out what is the bulk modulus K (in the unit of GPa) of water.
ANS: The density of water ρ = 1000 kg/m^3. Since V = sqrt(K/ρ), we have K = ρ V^2 = 1000 km/m^3 x (1500 m/s)^2 = 2.25 x 10^9 Pa = 2.25 GPa
b. please estimate the pressure (in the unit of GPa) at the bottom of the deepest ocean.
ANS: the deepest ocean is at Mariana trench 11000 km. The corresponding ressure P = ρ g h = 1000 kg/m^3 x 9.8 m/s^2 x 1.1x10^4 m = 9.8 x 1.1 x 10^7 Pa = 0.1078 x 10^9 Pa = 0.1078 GPa

c. would sound speed at the bottom of the deepest ocean higher or lower than 1.5 km/sec? Why?
ANS: Higher. Since after certain depth the water temperature does not change anymore, but the pressure keeps increasing with depth. Hence, the sound speed would also kept increasing with depth.

2. [15] If the near total silence is 0 dB with the sound intensity of 1 x 10^{-12} W/m^2, please find out the sound intensity (in the unit of W/m^2) for 140 dB that would produce immediate damage to human ears.
ANS: Since β = 10 dB log10 (I/I_o), we have I = 10^(β/10) x I_o = 10^14 x 10^-12 = 100 w/m^2.

3. [20] If the loudness of the blast heard at 160 km from the 1883 eruption of the Krakatoa volcano is calculated to be about 180 dB, please compute its sound intensity in the unit of W/m^2. Please estimate the maximum distance the blast can be heard by human ear. (Assume that there is no energy lost to other forms. Also the lowest level that human ear can hear is around 10 dB).
ANS: We have β = 10 dB log10 (I/I_o), and $I = P/(4 \pi r^2)$. *Hence* $I_1 r_1^2 = I_2 r_2^2$.
Since I_1 = 10^(β/10) x I_o = 10^18 x 10^-12 = 10^6 w/m^2,
I_2 = 10^(β/10) x I_o = 10^1 x 10^-11 = 10^-11 w/m^2.
So r_2 = sqrt (I_1/ I_2) r_1 = *sqrt (10^17)* r_1 = *5.06 x 10^10 km* (seems much larger than the Earth's radius – because we did not consider that the energy also attenuates to other forms).

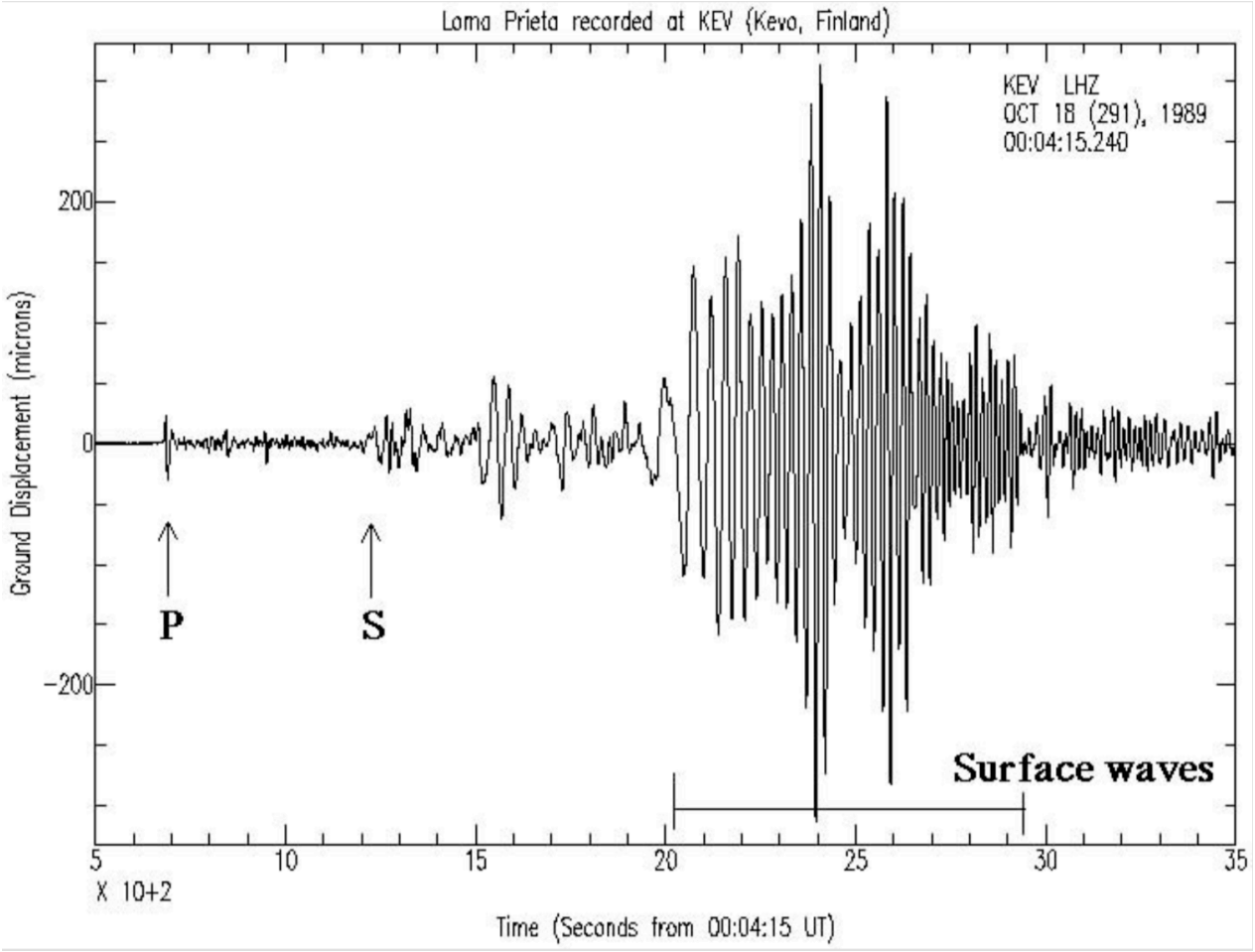
4. [20] Please compute how long it will take for earthquake surface waves and air waves to circle around the Earth. (Note: you need to find out a reasonable velocity for seismic surface waves and air waves).
ANS: The Earth's circumference is 2 x pi x r = 2 x 3.14 x 6371 km = 40009 km.
Surface wave speed is in the range of 3.5 to 4.5 km/s, and the air-wave speed is 343 m/s.
Hence, it takes 8891 – 11431 s (or 2.47 to 3.18 hours) for the surface waves to go around the Earth, and it takes about 32.4 hour for the air wave to circle around the Earth.

5. [25] The figure in the next page shows a vertical-component seismogram of the 1989 magnitude 6.9 Loma Prieta, California earthquake recorded in Finland.
a. Please estimate the dominant period, T, of the surface wave from its first ten cycles. Then component the corresponding frequency f = 1/T.

Ans: There are about 8 peaks in 200 s so the period is about 25 s. The corresponding frequency f = 1/T = 0.04 Hz

b. If the earthquake epicenter is at 37.04°N, 121.88°W, and the seismic station KEV is located at 69.7565°N, 27.0035°E, please find the great circle distance (in the unit of km) between these two location first (You can use any online tool or existing software to do so). Then compute the seismic speeds (in the unit of km/s) for the P wave, S wave, and the first cycle of the surface waves, by reading the travel time from the seismogram in the next page.
ANS: The travel time for the P, S and the first cycle of the surface waves are: 700 s, 1200 and 1900 s. The great circle distance between these two points are 7906 km.
Hence, the corresponding wave speeds are: 11.3 km/s, 6.6 km/s and 4.16 km/s.

c. Please estimate the wavelength (in the unit of km) for the P wave, S wave and the first cycle of surface waves (Note: you need to first find out the dominant period *T* for these waves from the graph).
ANS: The dominant period T for the P, S, and Surface waves are around 20, 40 to 60 s by reading from the graph below.
Hence, the corresponding wavelengths ($\lambda = V\,T$): 226 km, 263 km and 249 km.



Note: the x-axis in plotted between 500 seconds and 3500 seconds after the earthquake origin times.