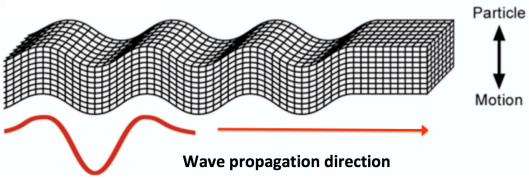
EAS 4801: Planetary Sound *NAME:*_____
Spring 2020 Exam
Note: Be sure to write neatly. If we can't understand what you wrote, you will not receive credit, no exceptions. Also make sure to provide detailed steps, rather than just the answers. Point values for individual problems are shown in bold brackets. Exam is worth a total of **[100]** pts.

Part I [30] Multiple Choices (3 point each):

1. This diagram on the right side shows a:
   a) P-Wave
   b) S-Wave
   c) Sound Wave
   d) Surface Wave

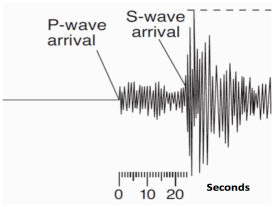


2. The lowest frequency that human ear can hear is about
   a) 0.02 Hz
   b) 2 Hz
   c) 20 Hz
   d) 20 KHz

3. What is the sound speed in iron?
   a. 343 m/s
   b. 1000 m/s
   c. 1500 m/s
   d. 5600 m/s

4. Which of the following activity likely produced the loudest sound/noise ever recorded on Earth?
   a. The 1883 Krakatoa volcanic eruption
   b. The launch of Saturn V rocket in 1960s
   c. The 2004 magnitude 9.3 Sumatra earthquake
   d. The most recent nuclear test in North Korea in 2017

5. The figure on the right side shows a seismic event recorded in a planetary body (including a planet, dwarf planet or planetary-like moon) in the solar system. Based on its waveform characteristics, it is likely occurred on the
   a. Moon
   b. Earth
   c. Mars
   d. Venus



6. Based on what you have learned in the class, please identify which earthquake is likely a supershear rupture?
   a. The 2002 magnitude 7.8 Denali Fault Earthquake in Alaska (Strike-slip faulting)
   b. The 2004 magnitude 9.3 Sumatra earthquake in Indonesia (Thrust faulting)
   c. The 1994 magnitude 6.7 Northridge earthquake in California (Thrust faultig)
   d. The 2020 magnitude 6.4 earthquake in Puerto Rico (Normal faulting)

7. Which of the following seismic phase likely has the longest period?
   a. P wave
   b. S wave
   c. Surface wave
   d. Free oscillations

8. Two cars travel on the same street. The driver in one car would press the honk, while the driver in the other car would hear the honk. Under what condition would the honk to be heard at the LOWEST frequency?

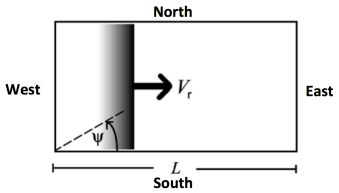
a. Two cars drive in the same direction to the left
b. Two cars drive in the same direction to the right
c. Two cars drive in the opposite direction toward each other
d. Two cars drive in the opposite direction away each other

9. If the string of a ukulele has a total length of 40 cm, what is the wavelength for second harmonic mode (note: the first higher mode above the fundamental mode)?

a) 10 cm
b) 20 cm
c) 40 cm
d) 80 cm

10. If an earthquake rupture has a speed of Vr, and is propagating from west to east (see the schematic diagram below). Which side would record the seismic ground motion with the lowest ground motion but extended duration?

a. West
b. East
c. North
d. South



Part II [30] Simple answers/definitions (10 point each. Feel free to draw diagrams if needed):

a. Please define what is the SOFAR channel (short for Sound Fixing And Ranging channel) (including how it is formed, and its effect for sound propagation).

ANS: SOFAR Channel is a horizontal layer of water in the ocean at which depth the speed of sound is at its minimum. The SOFAR channel acts as a waveguide for sound, and low frequency sound waves within the channel may travel thousands of miles before dissipating.

b. What is the Snell's law for wave propagation? Please draw how sound wave's incident angle changes when you have a sound wave enter the air-liquid interface.

Snell's law defines the refraction angle corresponding to the transmitted wave. Thus depending on the physical properties of each medium, the transmitted wave can be refracted either towards the vertical or towards the horizontal. When a sound wave hit the air-liquid interface from above, the incident angle will turn away from vertical, since the sound wave in the liquid is faster than in the air. The reverse is true.

c. What is the critical angle of incidence? What happens to the transmitted and reflected waves when the incident angle is larger than the critical angle of incidence?

When the **angle of incidence** in water reaches a certain **critical** value, the refracted ray lies along the boundary, having an **angle** of refraction of 90-degrees. This **angle of incidence** is known as the **critical angle**; it is the largest **angle of incidence** for which refraction can still occur.
The transmitted wave will disappear and all the wave will be reflected.

Part III [20] Simple calculations

1. [10] If the intensity of the sound wave is giving by the following equation: $I = \frac{(\Delta p)^2}{2\rho v_w}$, where I is the sound intensity (W/m^2), Δp is the pressure amplitude (Pa or $N/m2$), ρ is the density of medium (kg/m^3), and v_w is the sound speed in the medium (m/s), please compute

a) the sound intensity (in the unit of W/m^2) for a sound wave traveling in 20^{o}C air with a pressure amplitude of 0.5 Pa (the corresponding density of air is 1.2041 kg/m^3, and the sound speed is 343 m/s);

b) the corresponding sound intensity level β (Note: β = 10 dB log10 (I/I_o), I_o = 1 x 10^{-12} W/m^2).

$I = \frac{(\Delta p)^2}{2\rho v_w}$ = (0.5 Pa)^2/(2 x 1.2041 kg/m^3 x 343 m/s) = 0.000302 w/m^2

The corresponding sound intensity level β = 10 dB log10 (I/I_o) = 10 log10 (0.000302/1 x 10^{-12}) = 84.8 dB

2. **[10]** If an earthquake occurred at a depth of 8.66 km, and the observer is at 5 km of the epicenter, please compute

   a. The incident angle of the P wave when it reaches to the surface, if the P wave velocity is 6 km/s and is assumed to be a constant beneath the surface.

   b. If the seismic P wave can be converted into sound wave, please compute the incident angle of the sound wave when it leaves the surface. (Note: you can use the sound wave speed of 343 m/s)

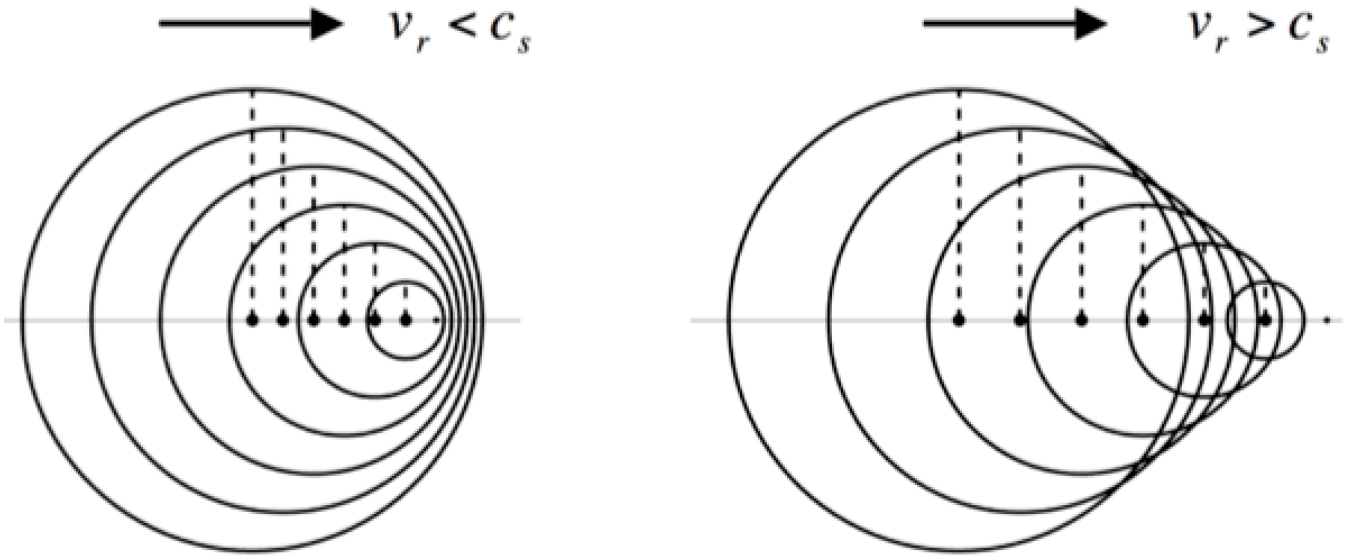
ANS: a. When the P wave reach to the surface, the incident angle of the P wave sin i_1 = 5 / sqrt (5x5 + 8.66 x 8.66) = 1/2. Hence, $i_1 = 30^o$.

b. Following Snell's law, sin i_2 / v_2 = sin i_1 / v_1

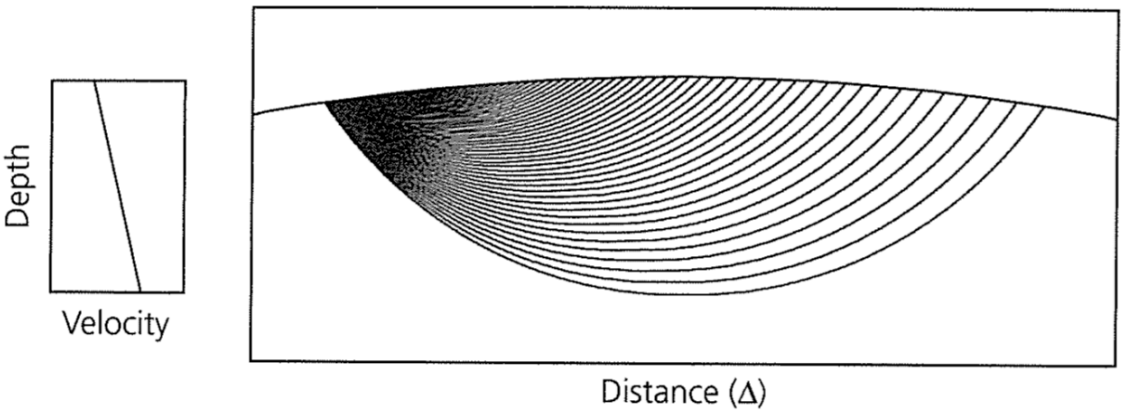
Hence, sin i_2 = ½ v_2 / v_1 = ½ 343/6000 = 0.0286. So i_2 = arcsin (0.0286) = 1.64 degree

Part IV [20] Simple graphics

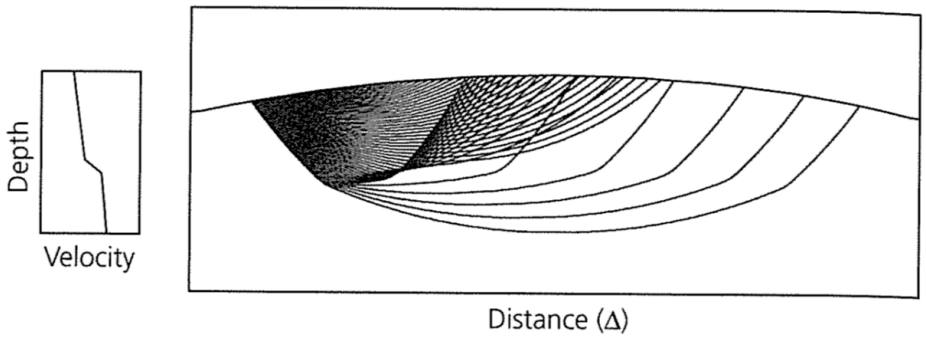
1. [10] Please illustrate how Doppler effect works by drawing a moving source (e.g., from left to right) and the corresponding wavefronts at different times/locations for two cases: a) sources moving at a speed lower than the sound speed; b) sources moving faster than the sound speed.



2. [10] Please follow the example below draw the seismic ray paths for the following two cases: a) a sudden velocity jump (e.g., sharp interface like the Moho); b) a low-velocity zone (e.g., like the outer core). Please briefly describe the resulting phenomenon in each case.
Example: seismic velocity increases monotonically with depth.



a) a sudden velocity jump (next page)



b) a low-velocity zone