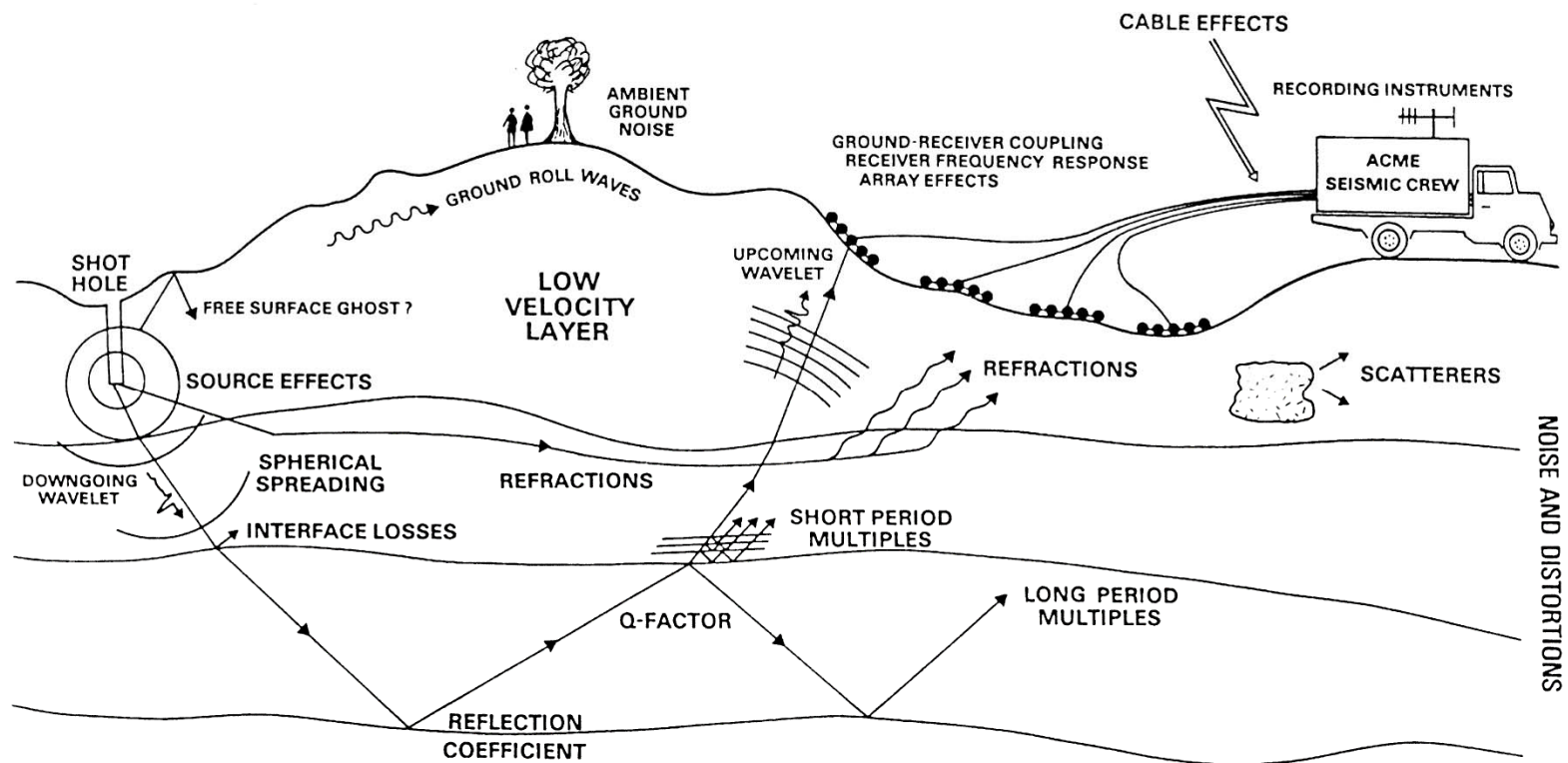


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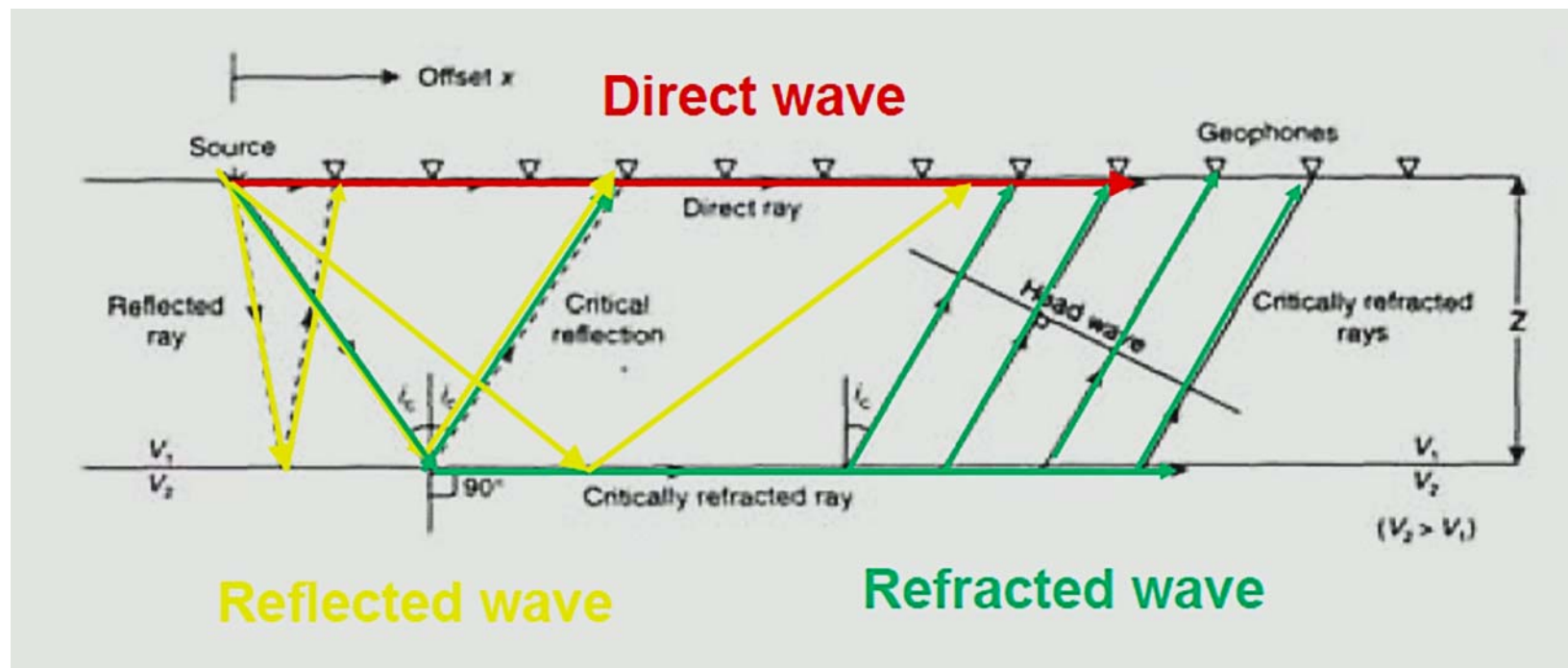
GPH 301

Geophysical Exploration

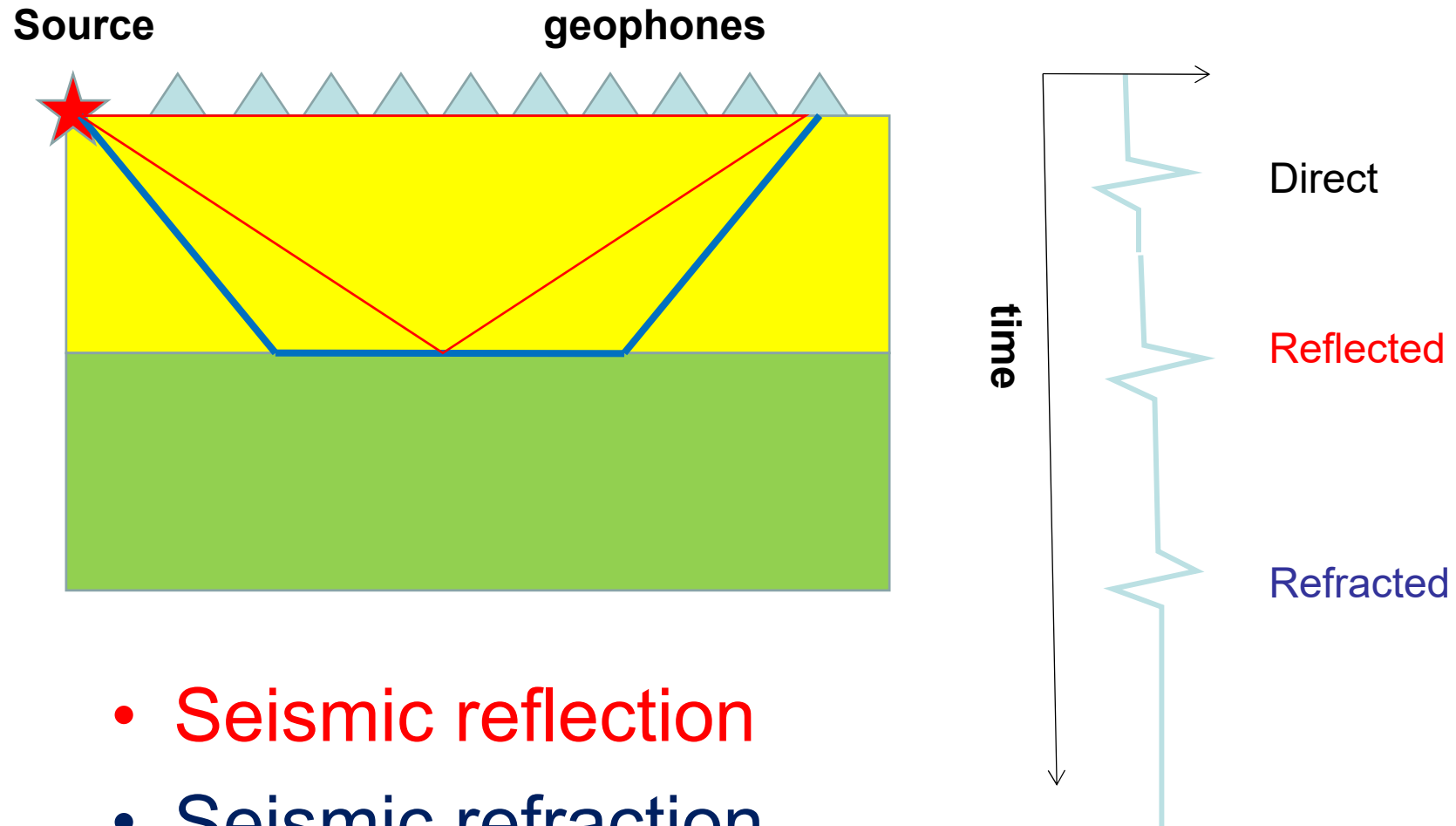
Dr. Sattam Abdulkareem Almadani

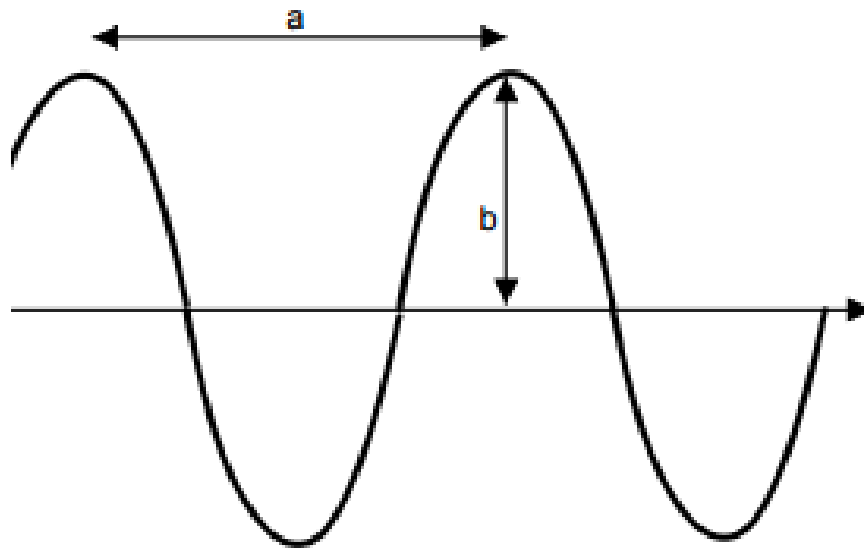


GPH 301 - Seismic Reflection Methods



Seismic Imaging Techniques





Generalities on the waves

b = amplitude

a = length of wave,

v = Velocity of propagation

λ = Wave length

f = frequency (hertz)

k = number of waves/ km

T = period = time for one cycle

K = wave number

$T = 1 / \text{frequency} = \text{wavelength} / \text{velocity}$

Wave length = velocity / frequency

Velocity = frequency * wavelength

Wave number = $1 / \text{Wavelength}$

Frequency = $1 / \text{period}$

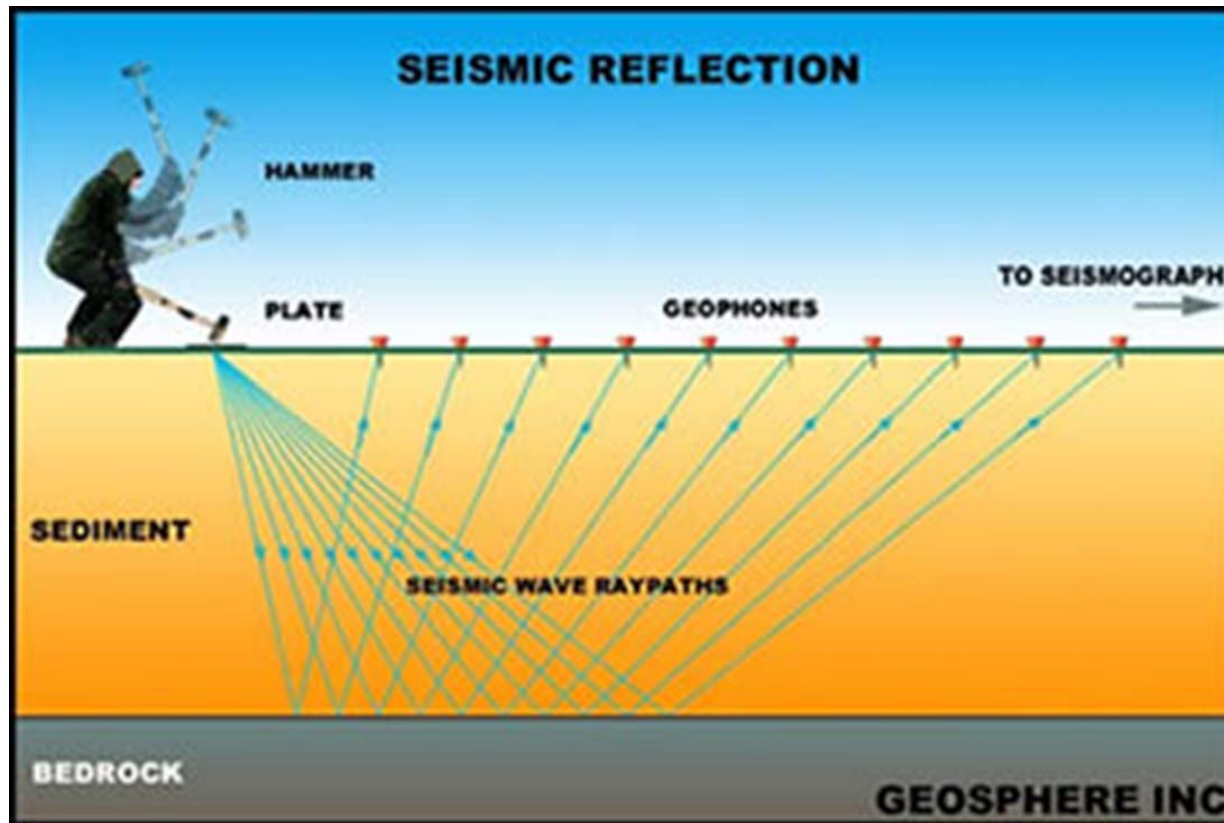
f / k = apparent velocity

T = period = length of a cycle

The seismic waves are elastic distortion waves, which propagate some various velocities into the rocks or along some layers limits.

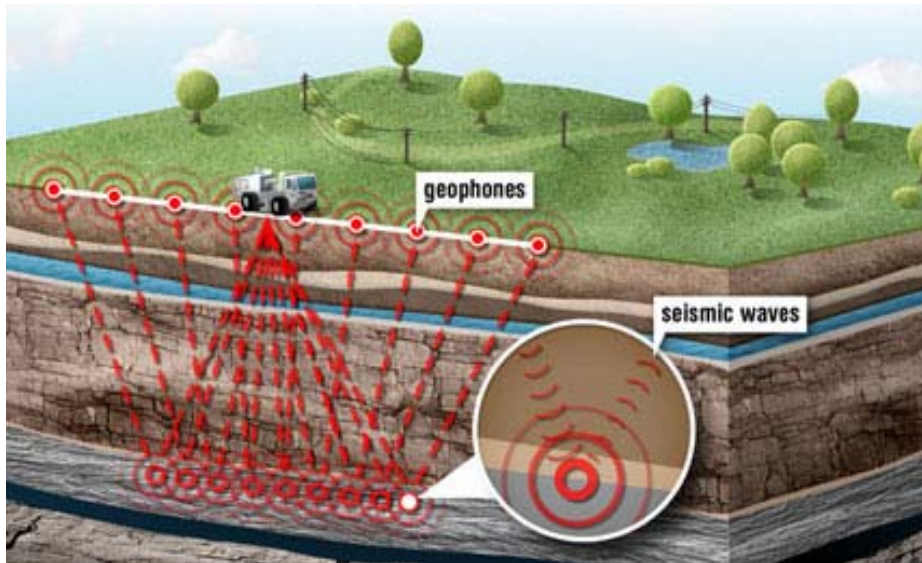
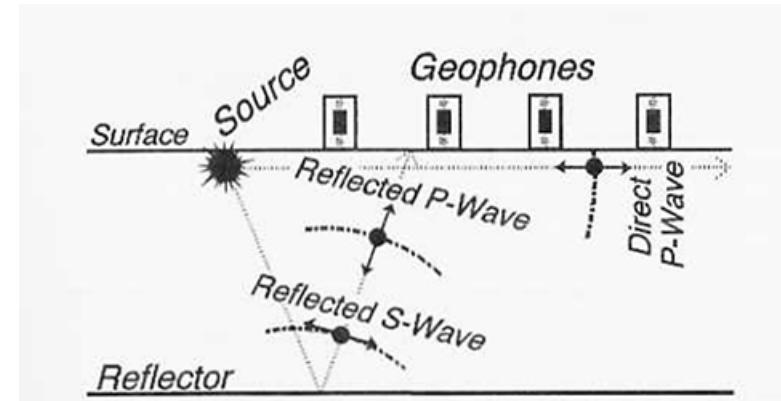
Q. What is seismic reflection?

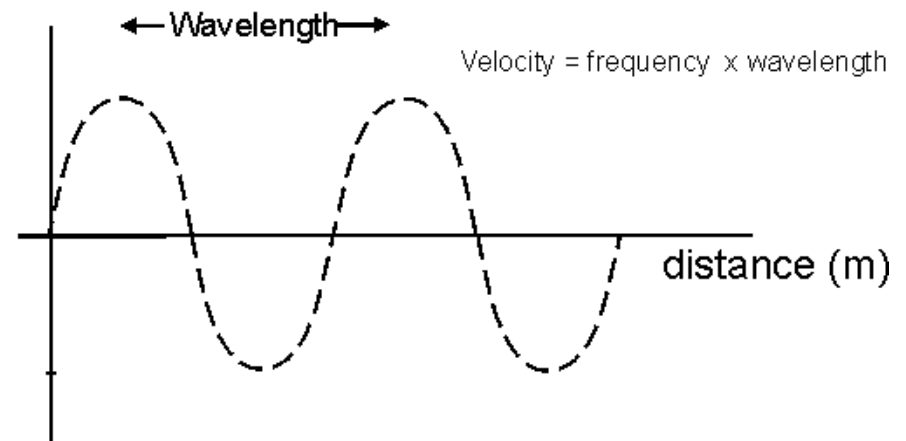
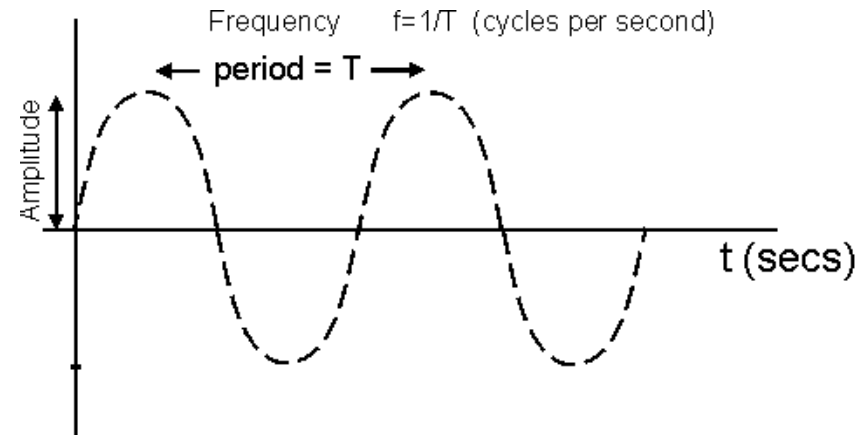
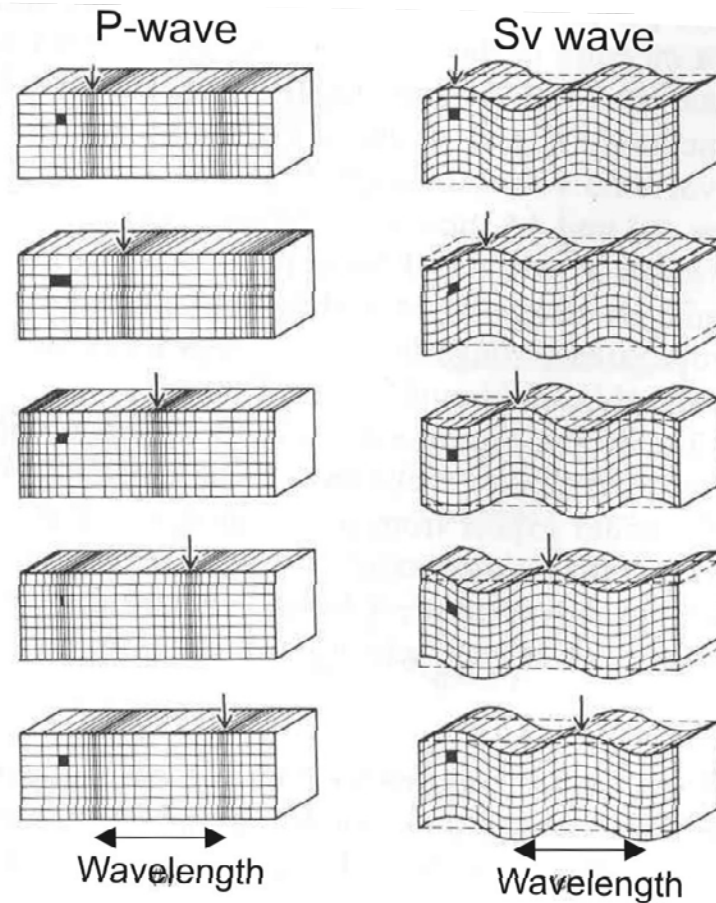
Seismic Refraction: A dynamic geophysical technique of generating a sound wave at a source and recording the time it takes for components of that seismic energy to return to the surface and be recorded by receivers.



Applications for seismic reflection:

- Detection of subsurface cavities.
- Shallow stratigraphy.
- Hydrocarbon exploration.
- Crustal structure and tectonics.





Normally only interested in p-wave (smallest amplitude/fastest)
 The higher the frequency the better – reflections appear sharper

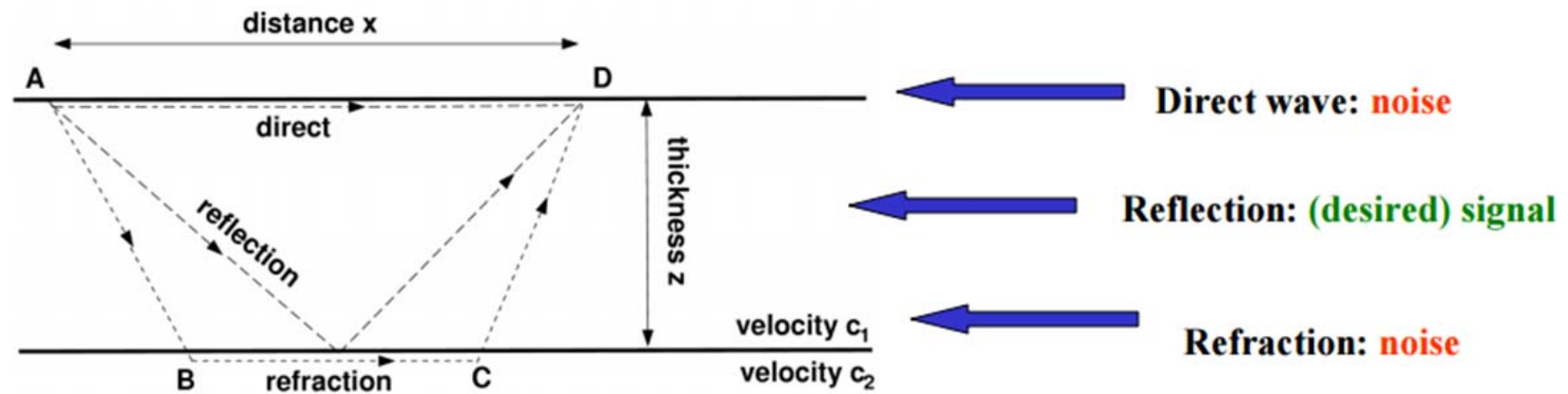
Signal and Noise

Signal: desired

Noise: not desired

So for reflection seismology:

- Primary reflections are signal
- Everything else is noise!



Seismic Reflection

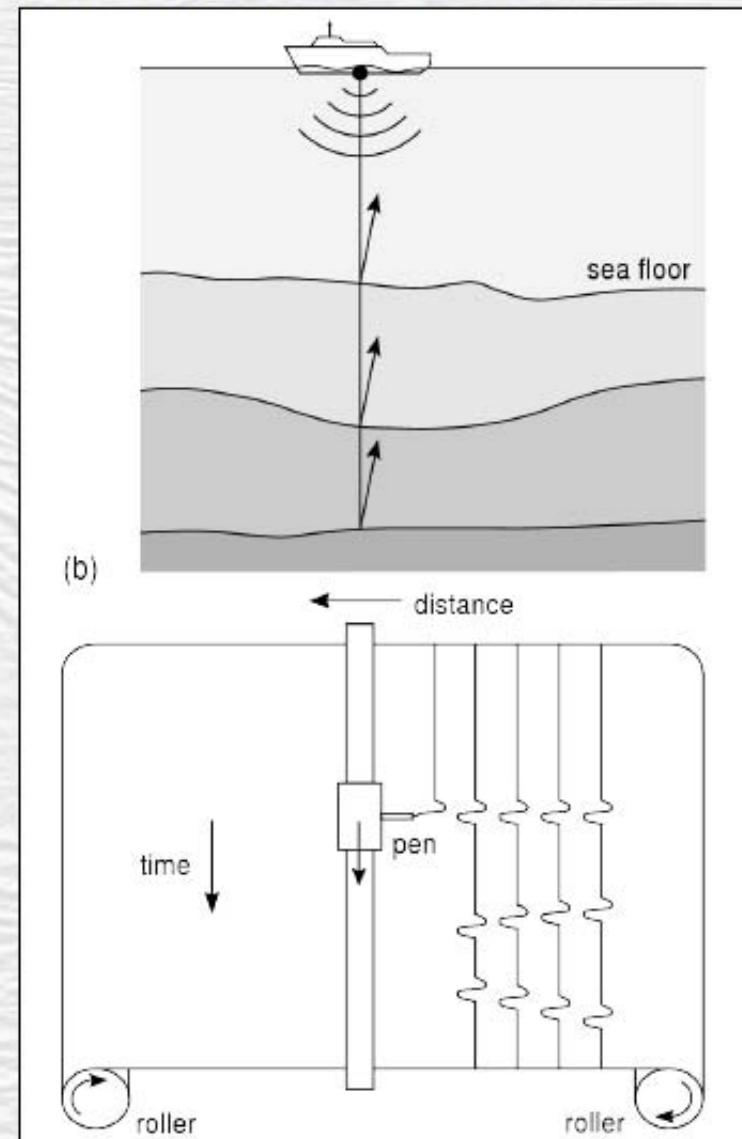
- Things to know before we start...
 - Seismic reflection is the single most important technique for seeing into the Earth.
 - It is useful for shallow and deep depths
 - Massively used by the oil and gas industry
 - It can detect:
 - Stratigraphy
 - Faults
 - Folds
 - Oil & Gas Reservoirs
 - Groundwater Resources
 - Why so popular?
 - Produces results that actually look a lot like an actual geologic cross section!!

Reflection Seismology

- 1920's - 1930's, seismic reflection developed for oil/gas exploration in sedimentary basins.
- Since 1970's, valuable in understanding structure of mid-lower crust.
- Popular for three main reasons:
 - Reflection data is commonly portrayed as profile resembling “geologic cross sections”.
 - Offers high resolution of subsurface data.
 - Cheaper than blindly drilling

Seismic Reflection :: The Basics

- In the simplest sense seismic reflection is echo sounding.
 - Echoes come from layers in the Earth, not fish or the sea floor
- E.g. a ship sends out a seismic pulse
 - The pulse is reflected back to a receiver on the ship's bottom after some time has passed
 - The various arrivals can be used to map out subsurface "reflectors" or layers



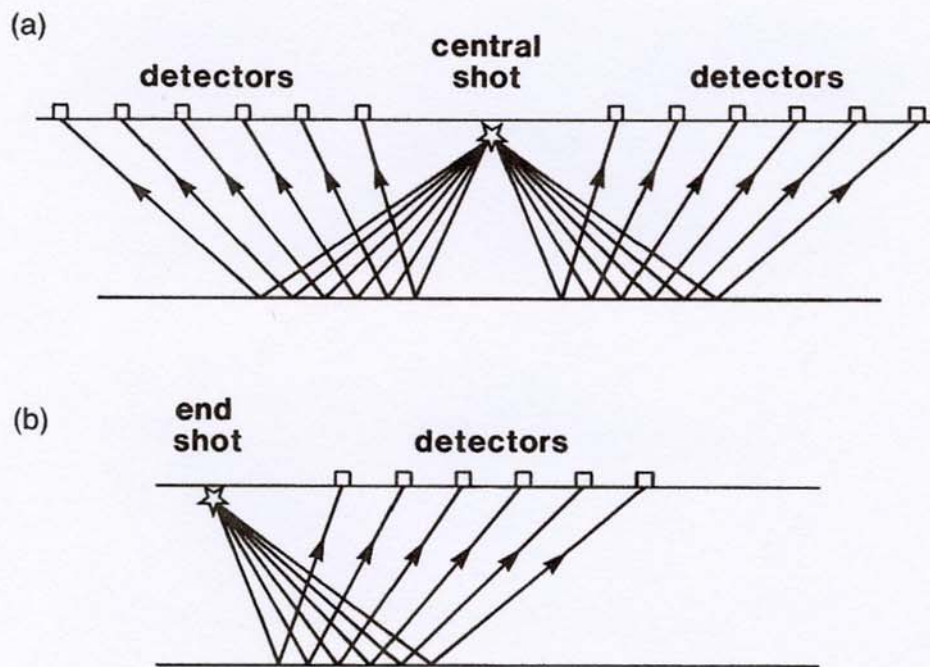


Fig. 4.6 Shot-detector configurations used in multichannel seismic reflection profiling. (a) Split spread, or straddle spread. (b) Single-ended spread.

Fundamental considerations:

- Reflection coefficient.
- Transmission coefficient
- Acoustic impedance.
- Zoeppritz equations.
- Negative polarity reflection
- Two-Way Time (TWT)

The **reflection coefficient** is the ratio of the amplitudes of the reflected and incident waves:

$$R = A_r/A_i$$

The **transmission coefficient** is the ratio of the amplitudes of the transmitted and incident waves:

$$T = A_t/A_i$$

The amount of energy that is partitioned into transmission and reflection depend on **the angle** between the incident wave and interface and on the **acoustic impedance (Z)** of each layer:

$$Z_1 = \rho_1 v_1 \quad \text{and} \quad Z_2 = \rho_2 v_2$$

For **normal incident waves**, it can be shown that:

$$R = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1} = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

$$T = \frac{2 \rho_1 v_1}{\rho_2 v_2 + \rho_1 v_1} = \frac{2Z_1}{Z_2 + Z_1}$$

These are the **Zoeppritz equations**. There are also more complicated forms of the Zoeppritz equations that can be used for any angle of incidence.

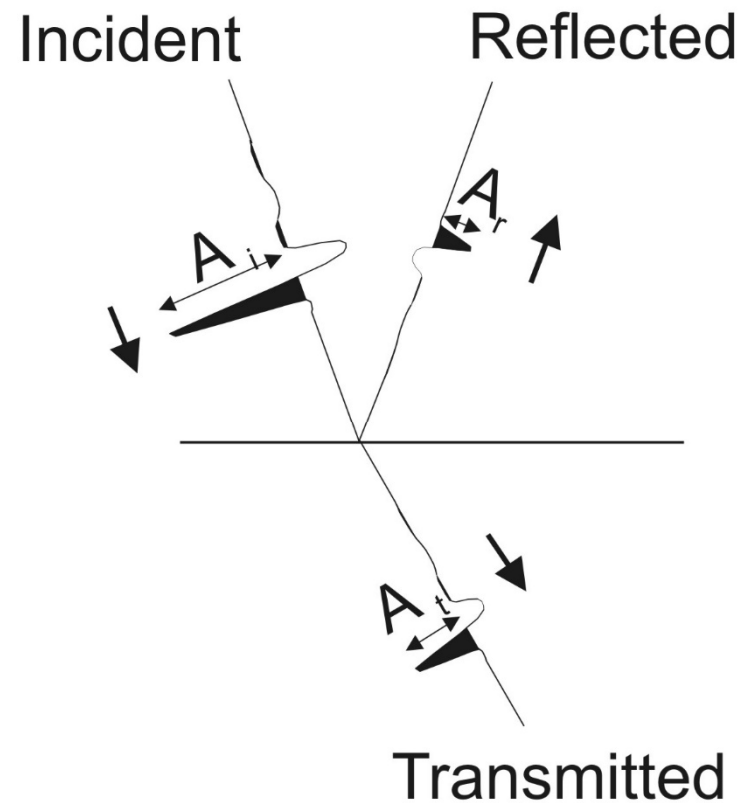
For small angle of incidence

$$R = \frac{A_r}{A_i}$$

$$R = \frac{v_2 \rho_2 - v_1 \rho_1}{v_2 \rho_2 + v_1 \rho_1}$$

$$T = \frac{A_t}{A_i}$$

$$T = \frac{2v_1 \rho_1}{v_2 \rho_2 + v_1 \rho_1}$$



These equations show that the reflection and transmission coefficients depend on the **difference in impedance** between the two layers.

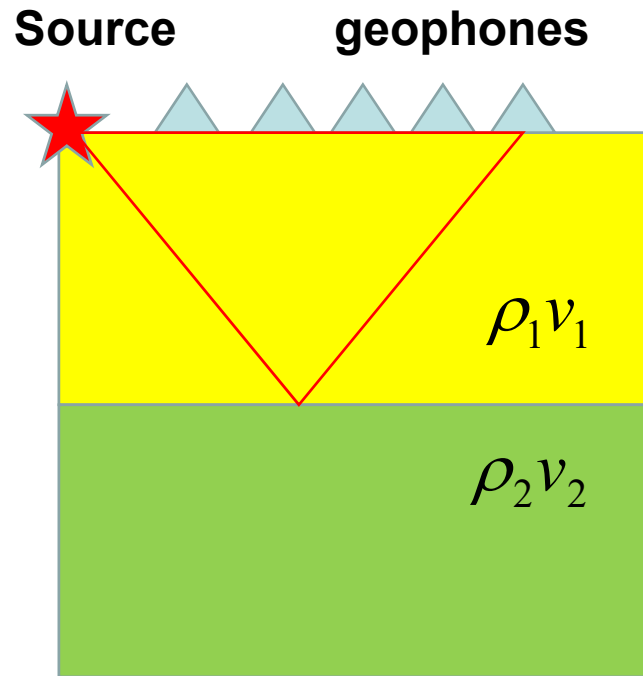
- If $Z_1 = Z_2$, there is no reflection. All energy is transmitted into the second layer. This does not mean that $\rho_1 = \rho_2$ and $v_1 = v_2$! All that matters is that **$\rho_1 v_1 = \rho_2 v_2$**

- **R** can have a value of +1 to -1. **R** will be negative when $Z_1 > Z_2$. A negative value means that there will be a phase change of 180° in the phase of the reflected wave (a peak becomes a trough). This is called a **negative polarity reflection**.

- **T** is always positive – transmitted waves have the same phase as the incident wave. **T** can be larger than 1.

- Reflection coefficients for the Earth are generally less than ± 0.2 , with maximum values of ± 0.5 . Most energy is transmitted, not reflected.

Seismic Reflection



Reflection coefficient
$$R = \frac{\rho_2 v_2 - \rho_1 v_1}{\rho_1 v_1 + \rho_2 v_2}$$

A typical value for R is 0.001

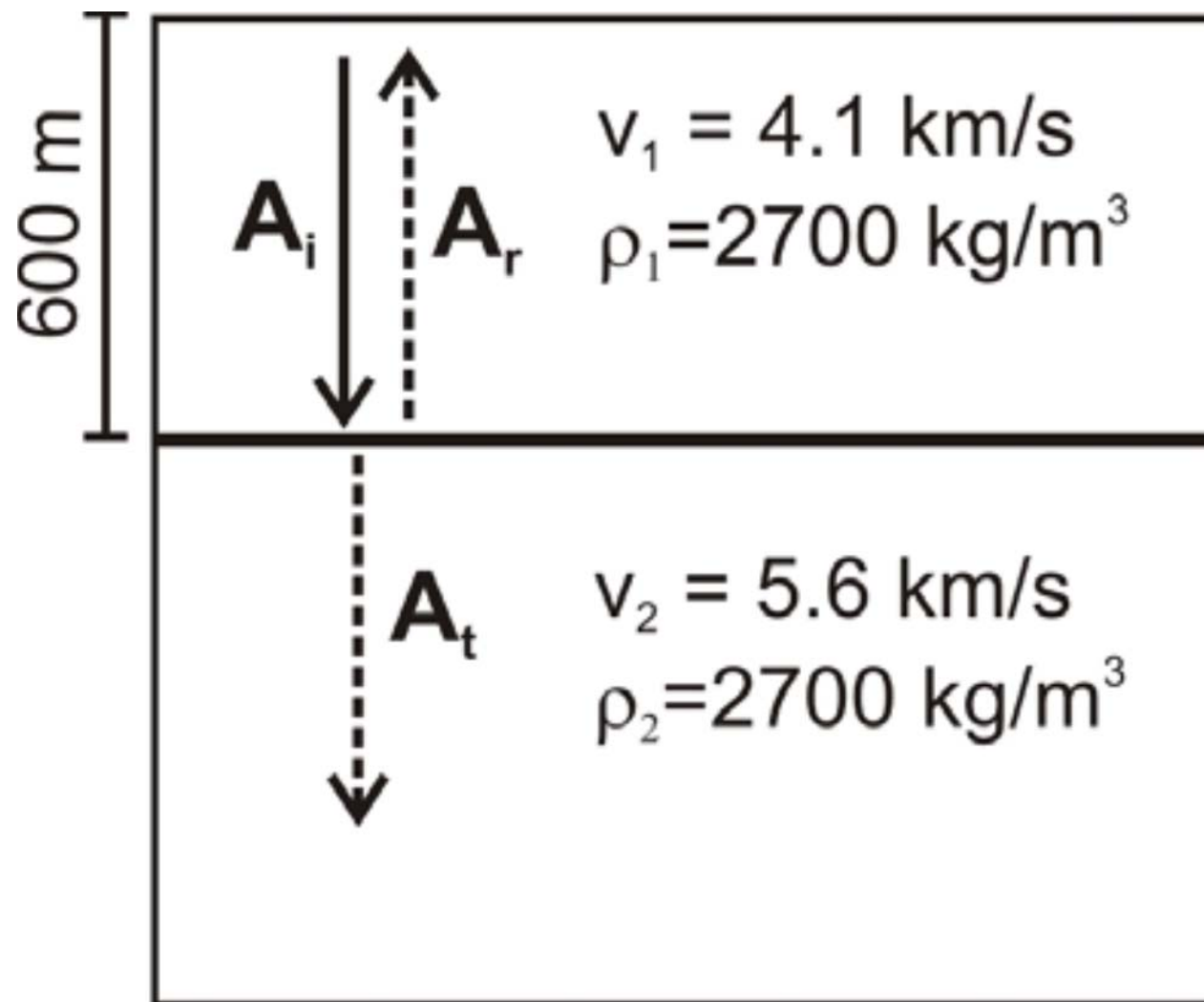
Reflectors reflect **contrasts of acoustic impedance**: $\rho \cdot v_p$

Polarity of reflected wave depends on sign of reflection coefficient

Case 1: An increase in velocity with depth

A 600 m thick layer of sandstone overlies a granite basement with a higher velocity. A seismic wave is generated at the surface and travels vertically downward. At the sandstone granite interface, the incident wave is split into a reflected wave and transmitted wave. The amplitude of the reflected and transmitted waves (A_r and A_t) can be calculated from the Zoeppritz equations. Assume that $A_i = 1.0$ and that there is no geometrical spreading, attenuation, or scattering. Velocity and density are constant within each layer. Calculate:

- a) The acoustic impedance (Z) of each layer
- b) R and T
- c) The amplitude of the two waves?



a) The acoustic impedance (Z) of each layer:

$$Z_1 = \rho_1 v_1 = 2700 \times 4.1 = 11,070 \text{ (kg km s}^{-1} \text{ m}^{-3}\text{)}$$

$$Z_2 = \rho_2 v_2 = 2700 \times 5.6 = 15,120 \text{ (kg km s}^{-1} \text{ m}^{-3}\text{)}$$

b) R and T :

The reflection and transmission coefficients are then:

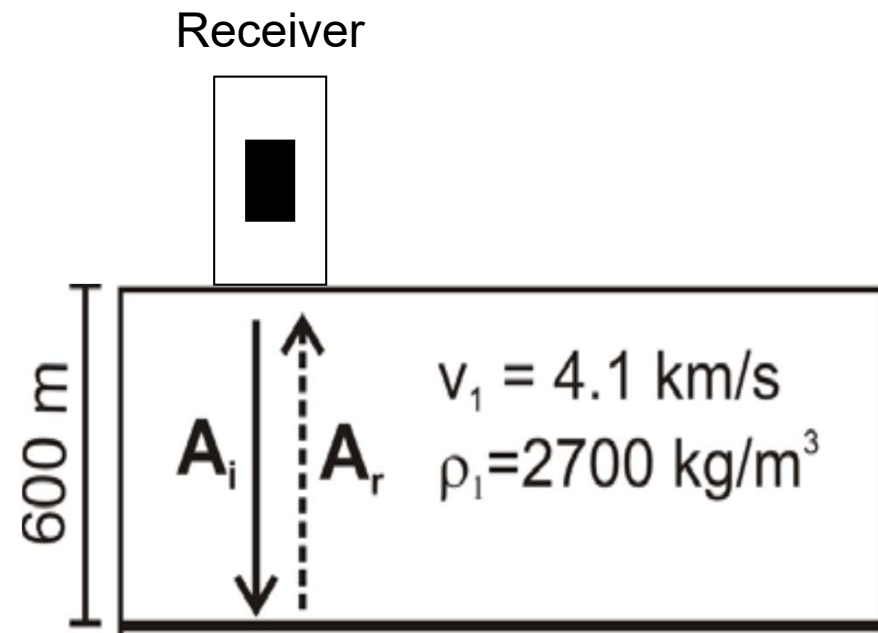
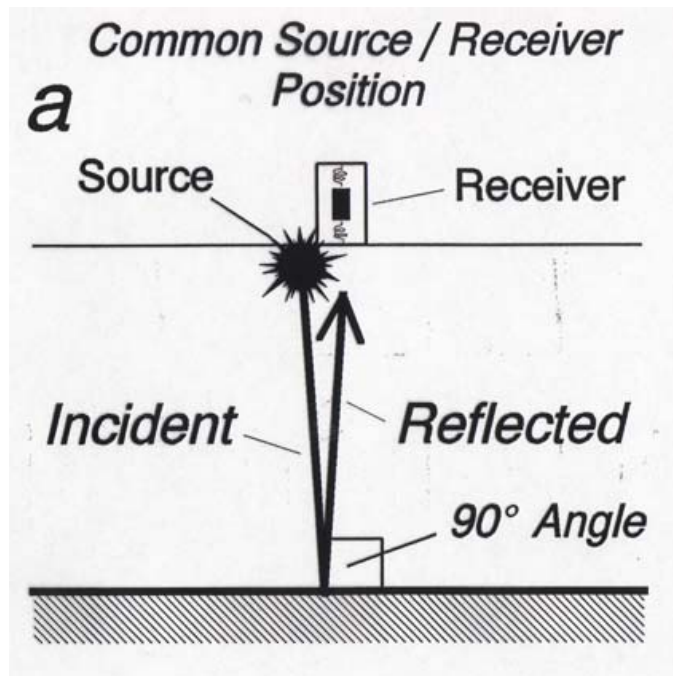
$$R = 0.15, \quad T = 0.85$$

c) The amplitude of the two waves:

$$A_r = R \times A_i = 0.15$$

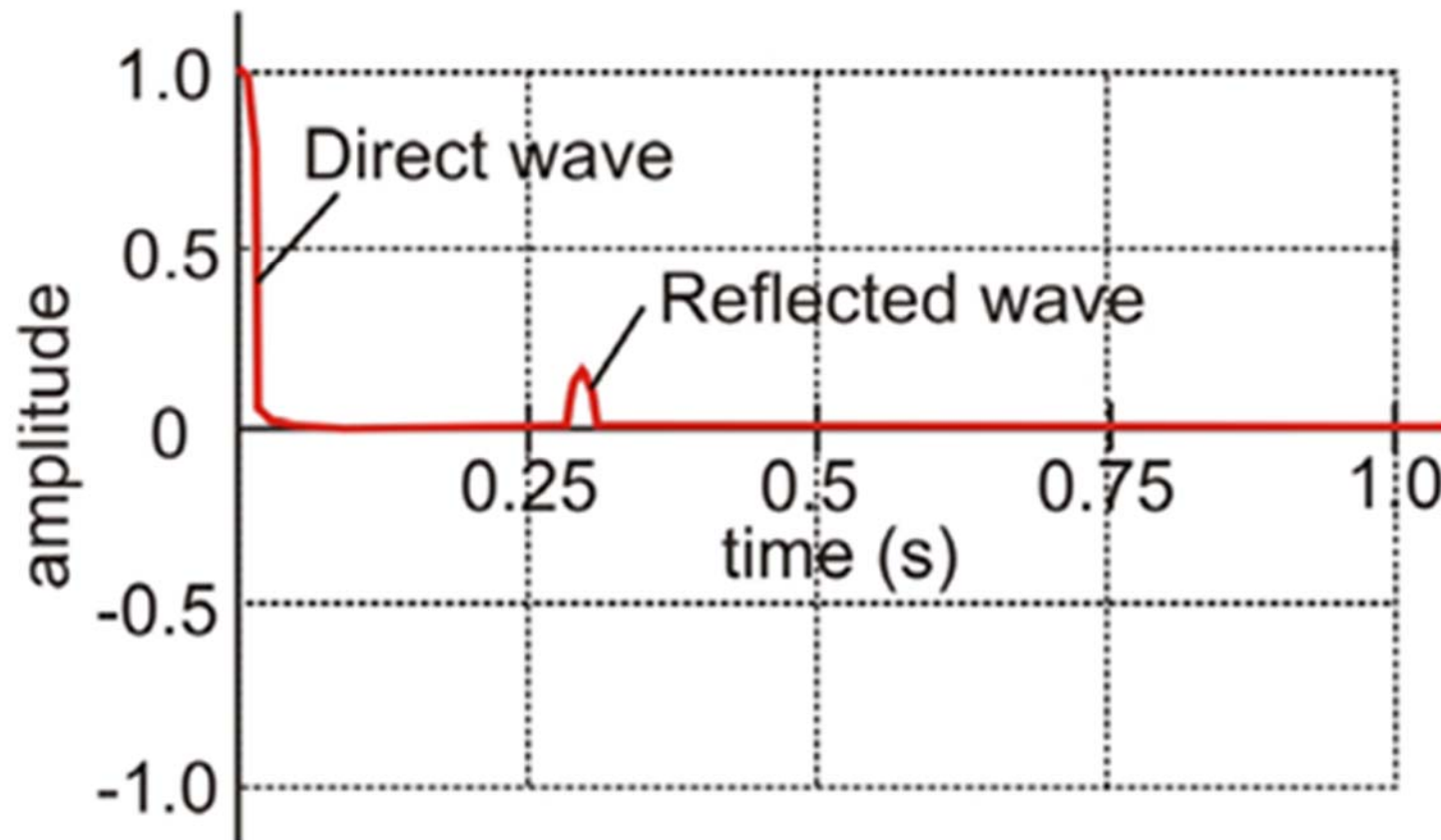
$$A_t = T \times A_i = 0.85$$

Q. Calculate the arrival time for the wave?



$$\text{Time} = 2 \times 600 / 4100 = 0.29\text{s}$$

The seismic record will look like this:

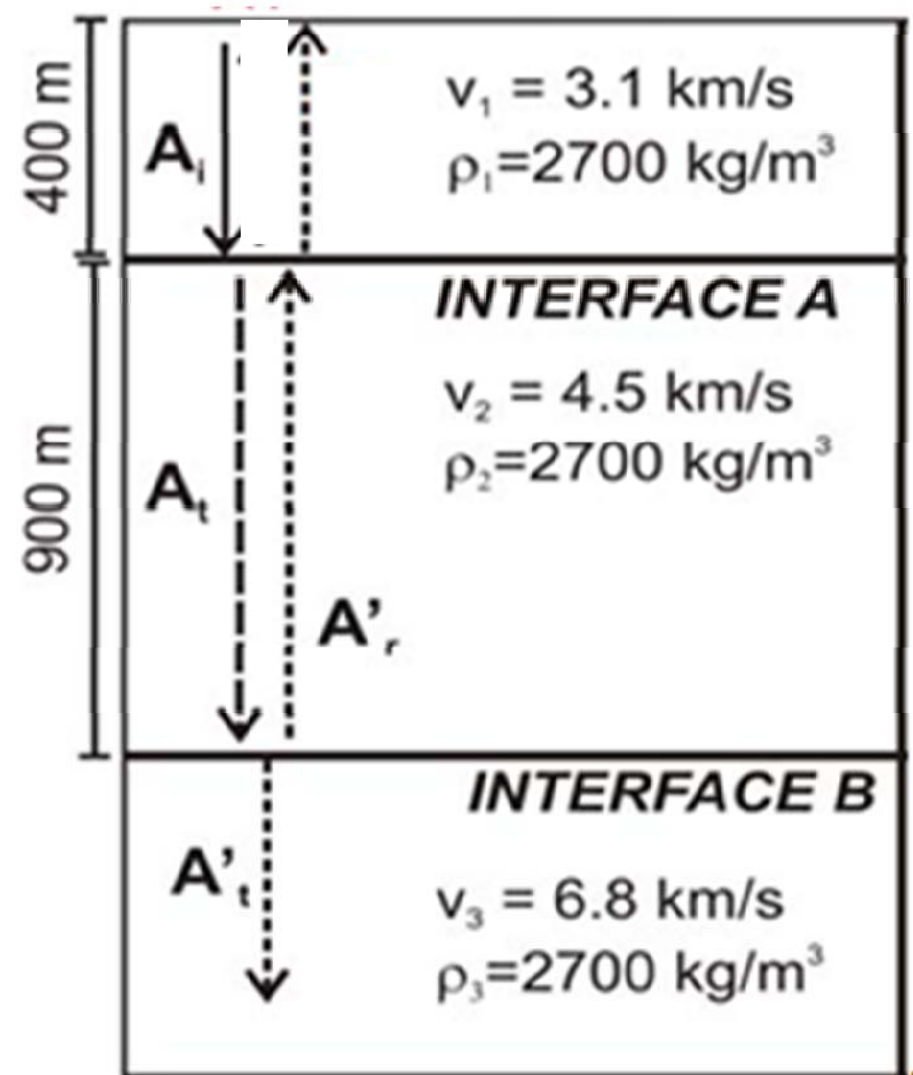


Calculate:

a) R and T for interface A

b) R and T for interface B

c) Total arrival time



a) $Z_1 = 8370 \text{ kg km s}^{-1} \text{ m}^{-3}$

$$Z_2 = 12150 \text{ kg km s}^{-1} \text{ m}^{-3}$$

$$R_A = 0.18 \text{ and } T_A = 0.82$$

Arrival time for interface A = 0.26 sec

b) $Z_2 = 12150 \text{ kg km s}^{-1} \text{ m}^{-3}$

$$Z_3 = 18360 \text{ kg km s}^{-1} \text{ m}^{-3}$$

$$R_B = 0.20 \text{ and } T_B = 0.80$$

Arrival time for interface B = 0.4 sec

c) Total arrival time = $0.26 + 0.4 = 0.66 \text{ sec}$