بسم الله الرحمن الرحيم

GPH 201

Principles of Geophysics

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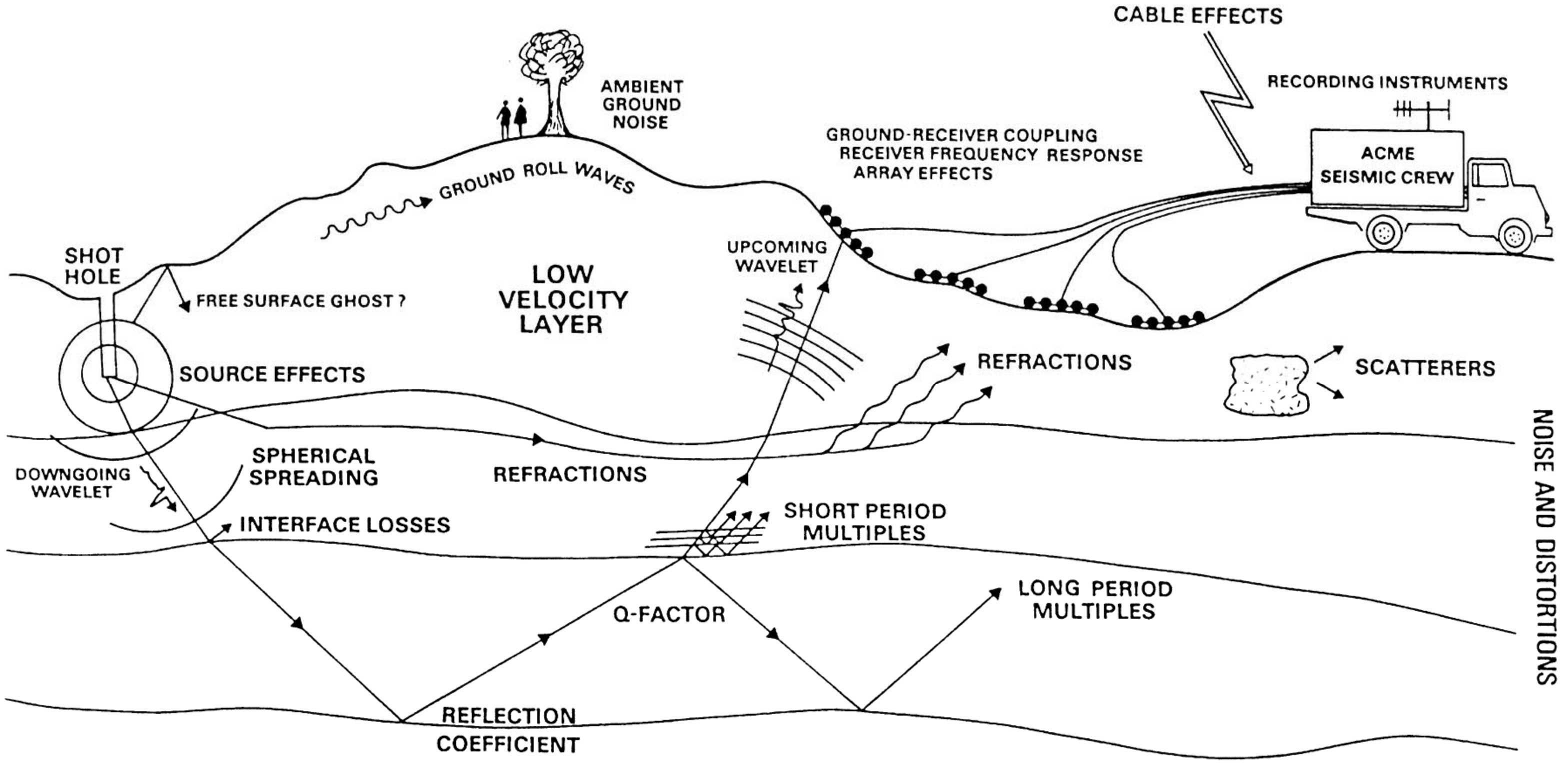
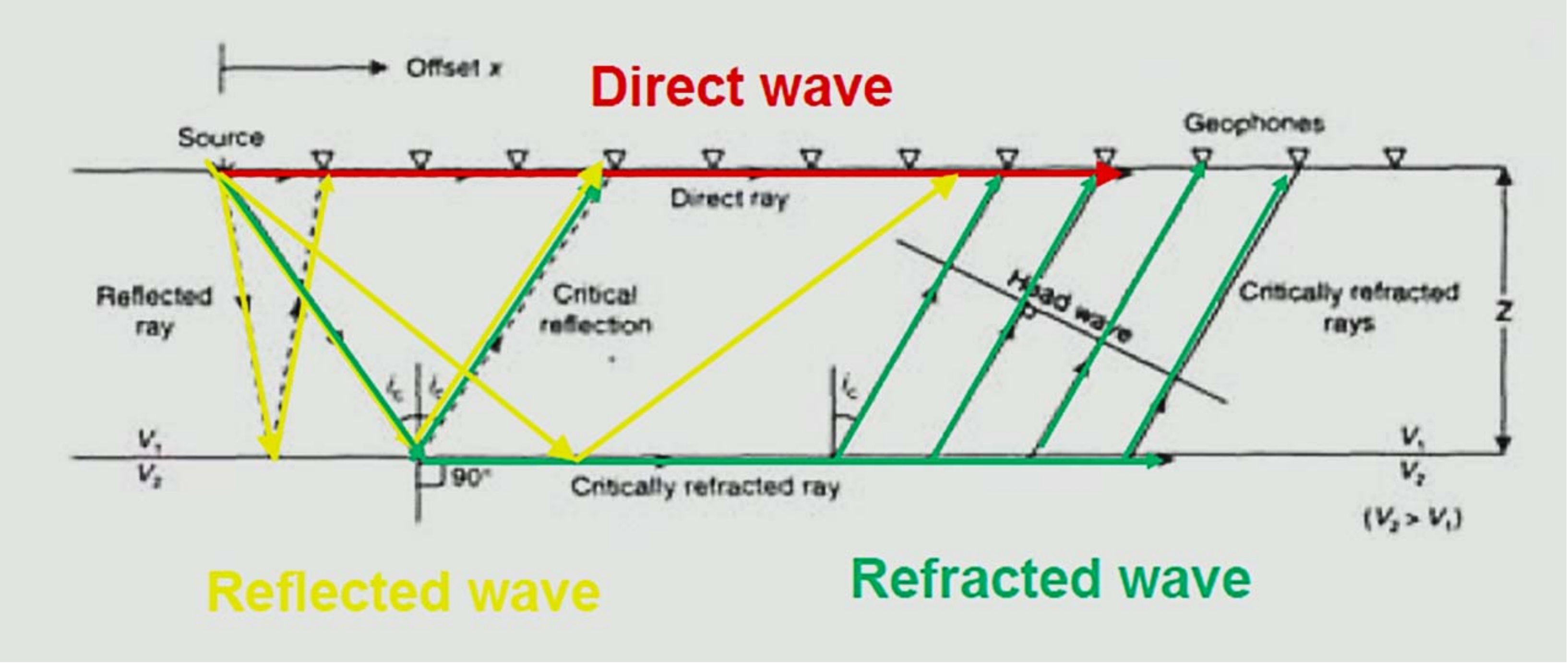
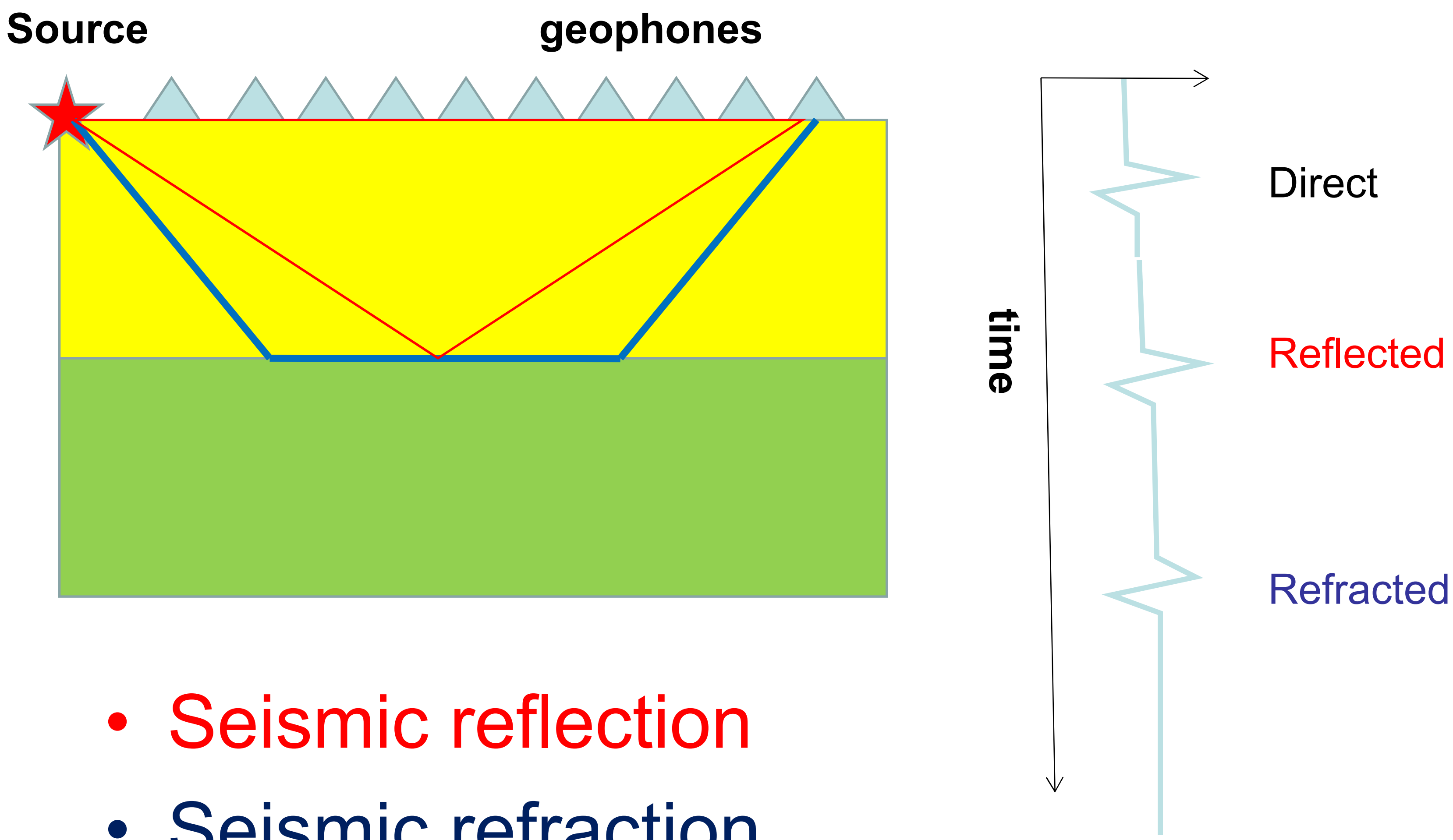


CABLE EFFECTS
RECORDING INSTRUMENTS
AMBIENT GROUND NOISE
GROUND-RECEIVER COUPLING
RECEIVER FREQUENCY RESPONSE
ARRAY EFFECTS
ACME SEISMIC CREW
GROUND ROLL WAVES
SHOT HOLE
FREE SURFACE GHOST ?
LOW VELOCITY LAYER
UPCOMING WAVELET
SOURCE EFFECTS
REFRACTIONS
SCATTERERS
NOISE AND DISTORTIONS
DOWNGOING WAVELET
SPHERICAL SPREADING
REFRACTIONS
INTERFACE LOSSES
SHORT PERIOD MULTIPLES
Q-FACTOR
LONG PERIOD MULTIPLES
REFLECTION COEFFICIENT

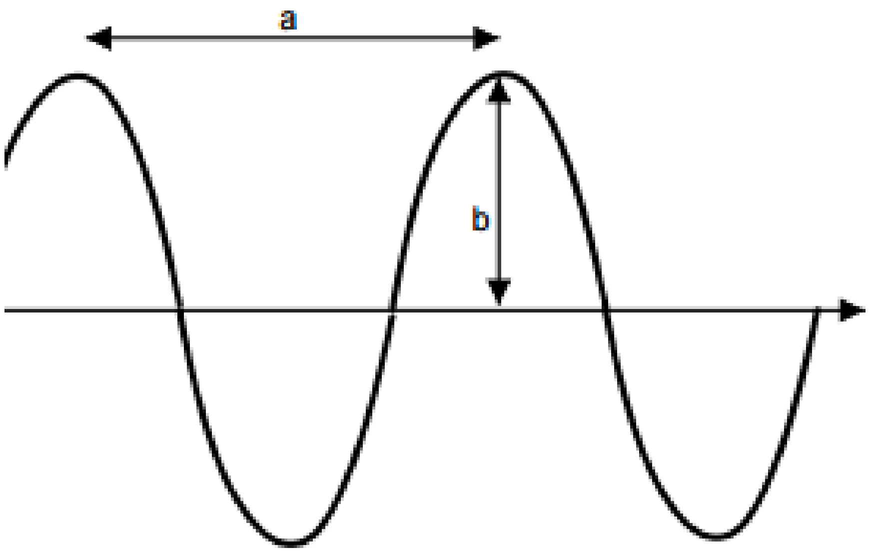


Offset x
Direct wave
Source
Geophones
Direct ray
Reflected ray
Critical reflection
Head wave
Critically refracted rays
Z
V1
V2
90°
Critically refracted ray
(V2 > V1)
Reflected wave
Refracted wave

Seismic Imaging Techniques



- Seismic reflection
- Seismic refraction



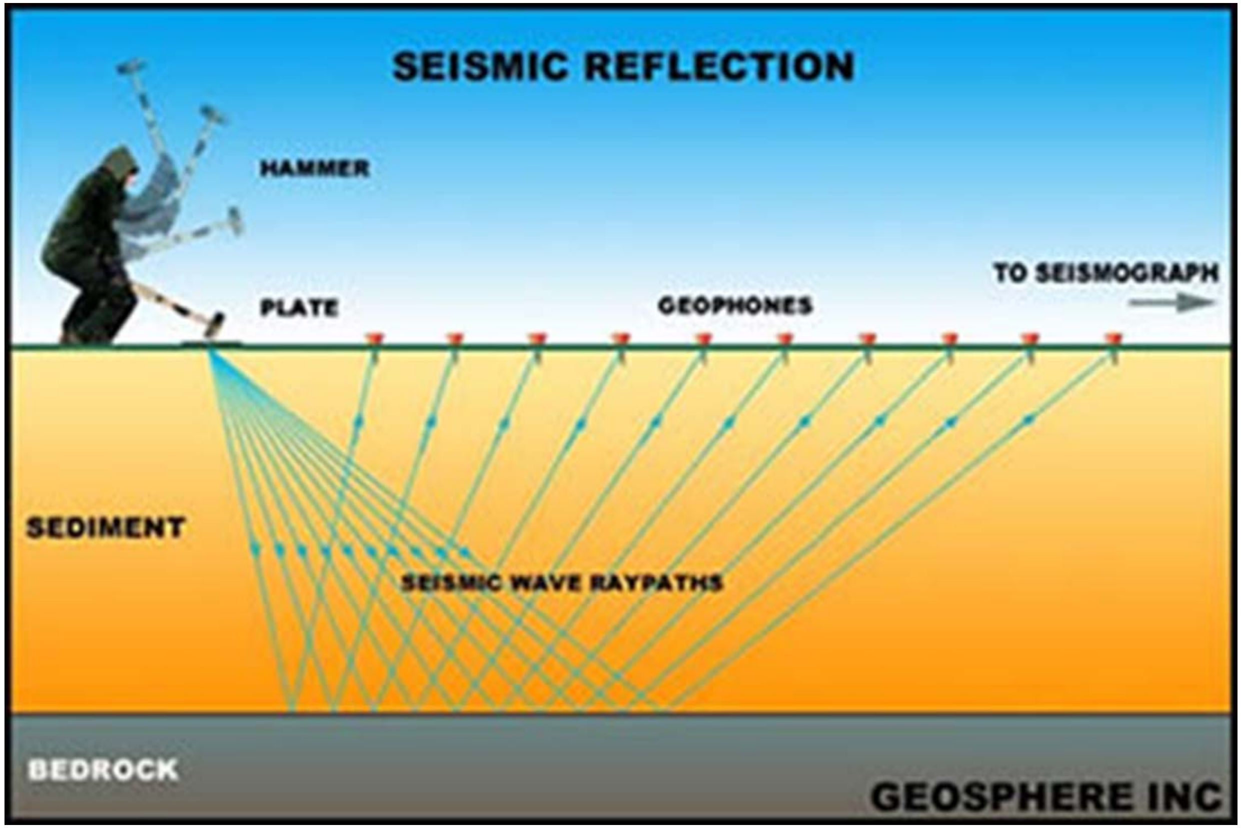
Generalities on the waves

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 / frequency = wavelength / velocity
Wave length = velocity / frequency
Velocity = frequency * wavelength
Wave number = 1 / Wavelength

Frequency = 1/ 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.

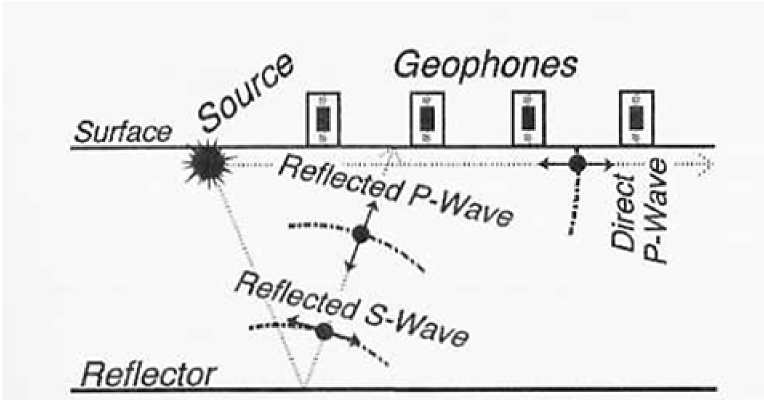
Q. What is seismic reflection?

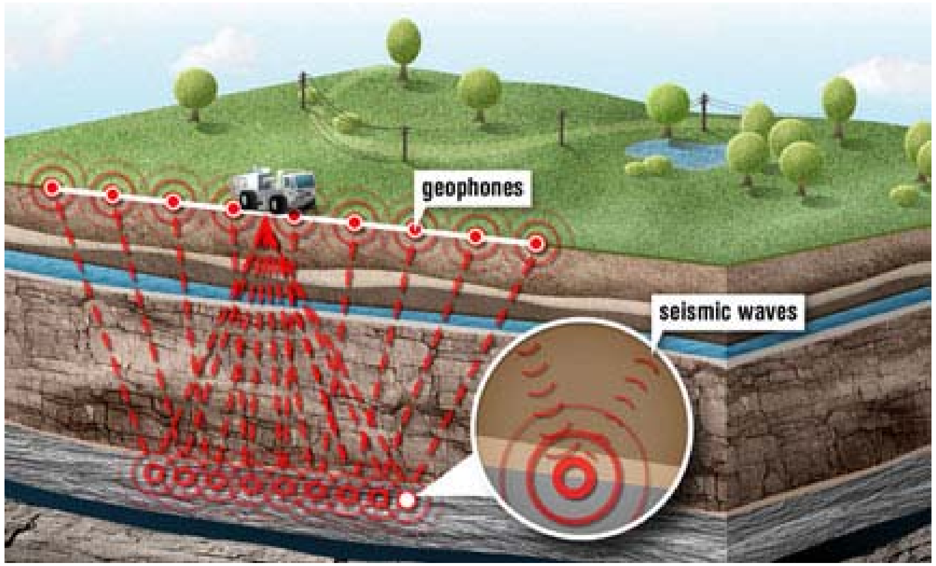
Seismic Refraction: A dynamic geophysical technique of generating a sound wave at a source and recording the time it takes for components of that seismic energy to return to the surface and be recorded by receivers.

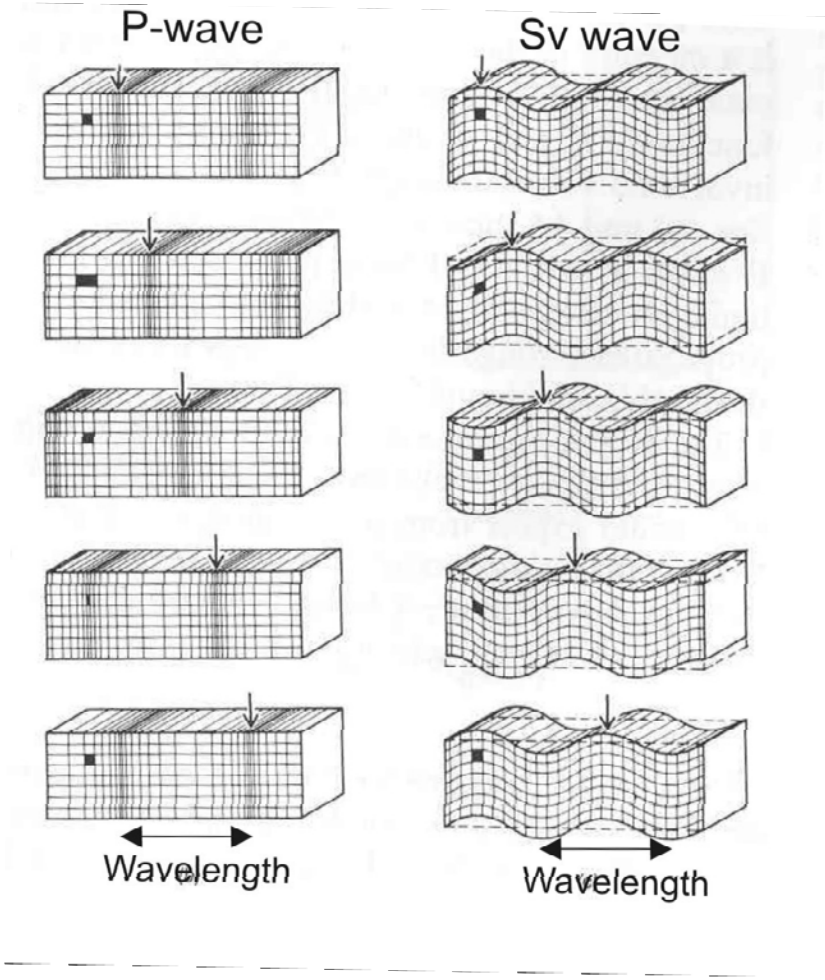


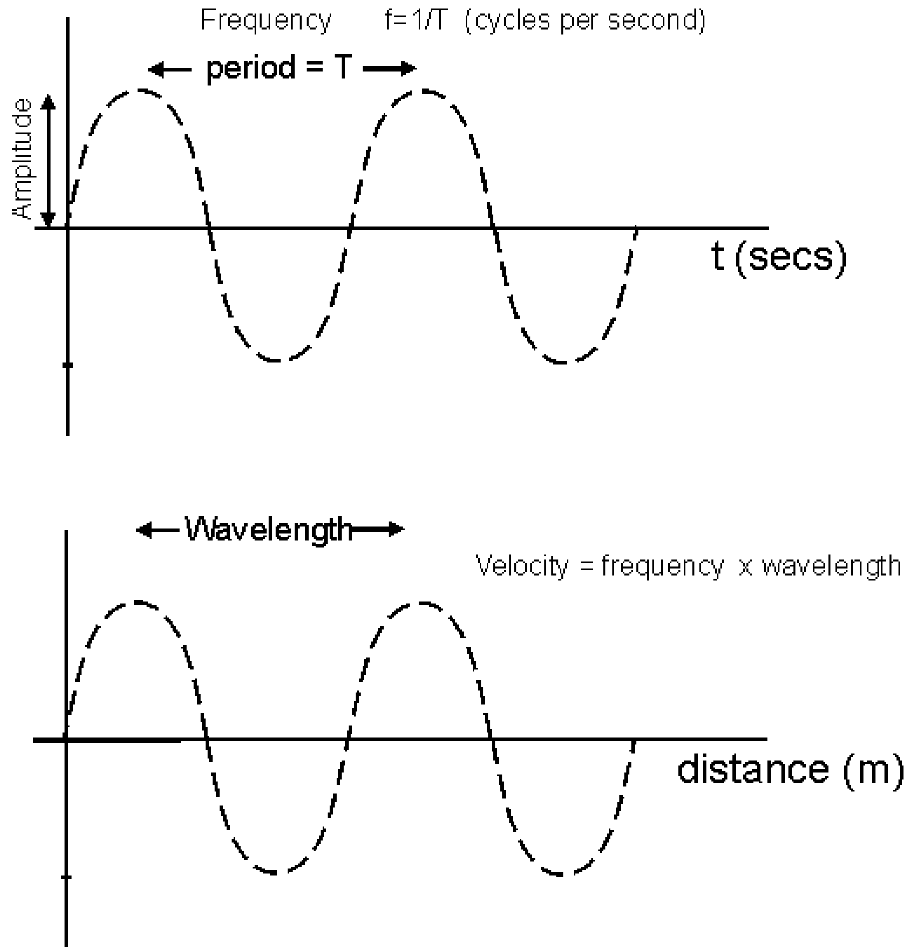
Applications for seismic reflection:

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









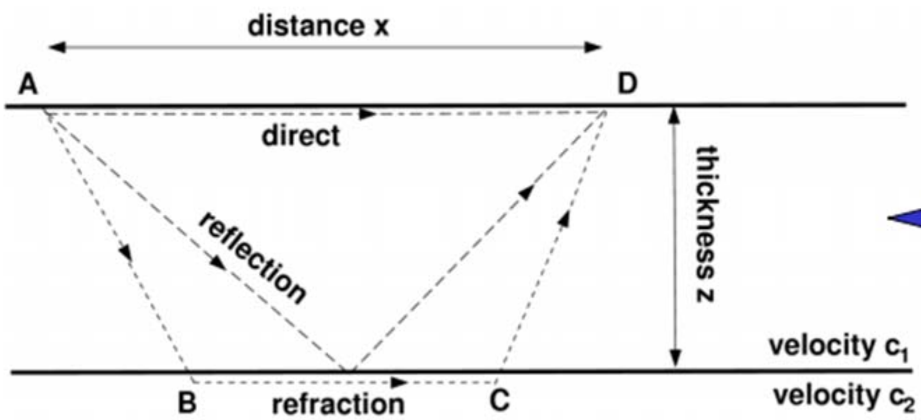
Normally only interested in p-wave (smallest amplitude/fastest)

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!



Direct wave: noise

Reflection: (desired) signal

Refraction: noise

Seismic Reflection

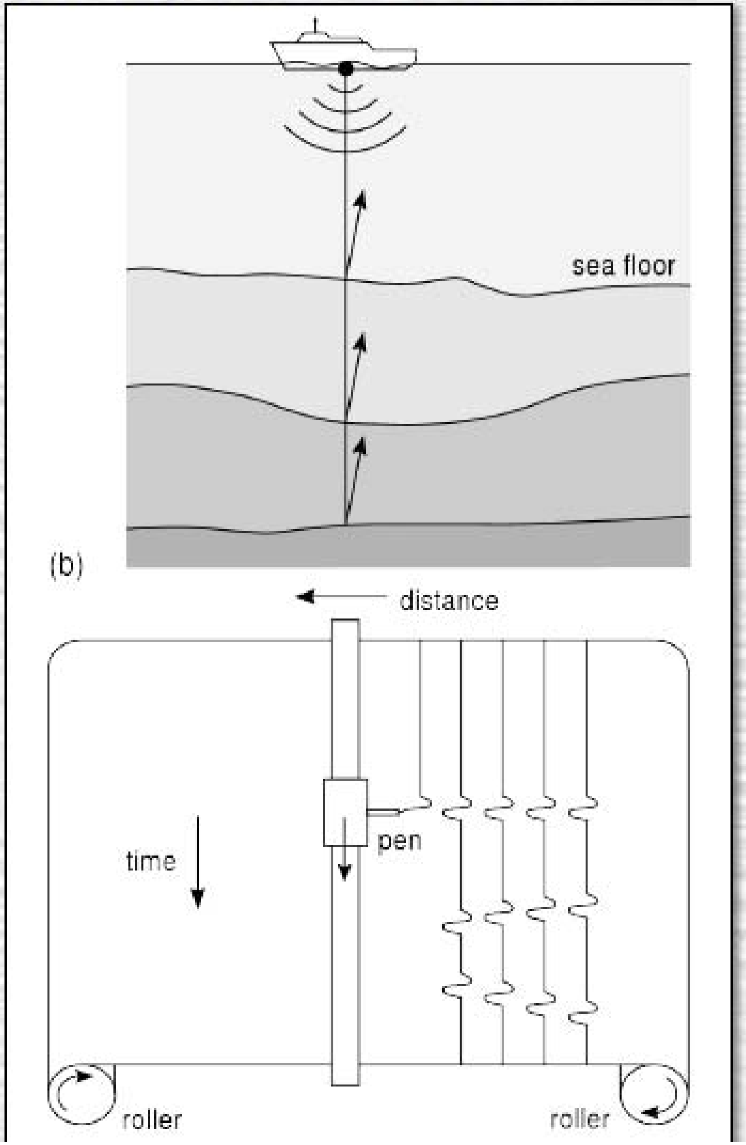
- Things to know before we start…
  - Seismic reflection is the single most important technique for seeing into the Earth.
    - It is useful for shallow and deep depths
    - Massively used by the oil and gas industry
    - It can detect:
      - Stratigraphy
      - Faults
      - Folds
      - Oil & 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



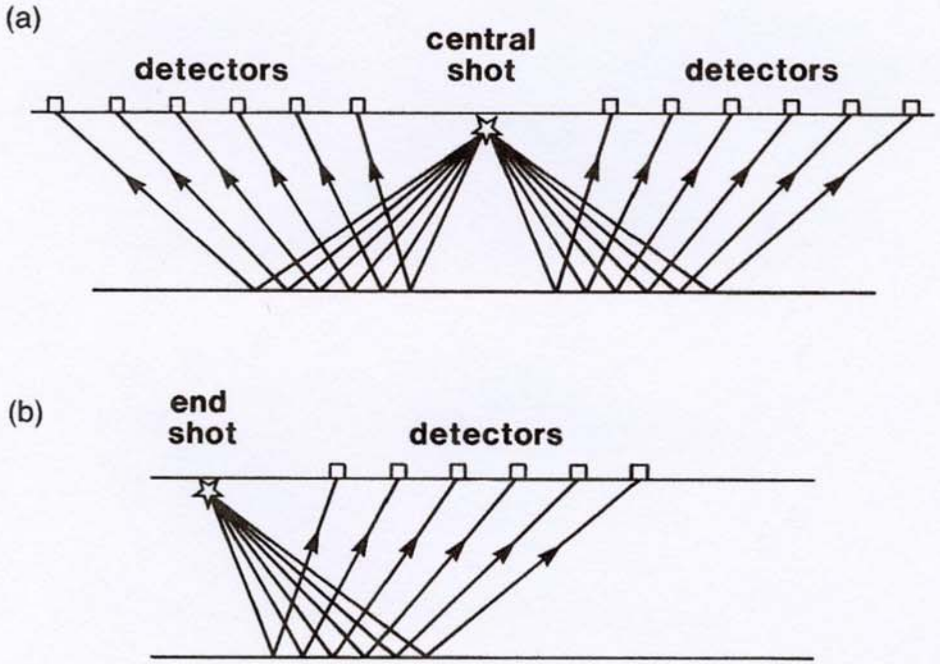


Fig. 4.6 Shot-detector configurations used in multichannel seismic reflection profiling. (a) Split spread, or straddle spread. (b) Single-ended spread.

Fundamental considerations:

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

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

$$R = Ar/Ai$$

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

$$T = At/Ai$$

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:

$$Z1 = \rho 1 v1 \quad \text{and} \quad Z2 = \rho 2 v2$$

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

$$R = \rho_2 v_2 - \rho_1 v_1 / \rho_2 v_2 + \rho_1 v_1 = Z_2 - Z_1 / Z_2 + Z_1$$

$$T = 2\rho_1 v_1 / \rho_2 v_2 + \rho_1 v_1 = 2Z_1 / Z_2 + Z_1$$

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

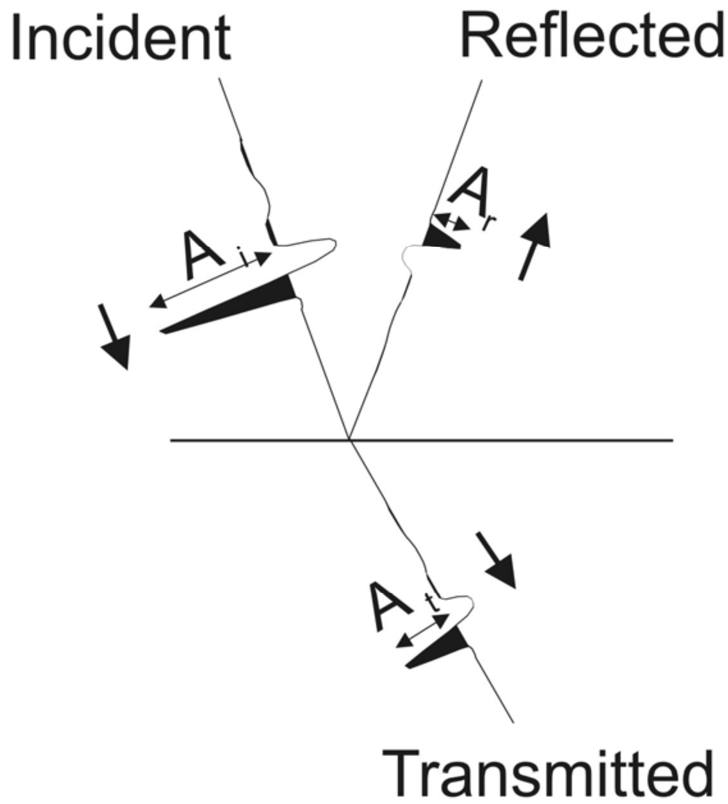
For small angle of incidence

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

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

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

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



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

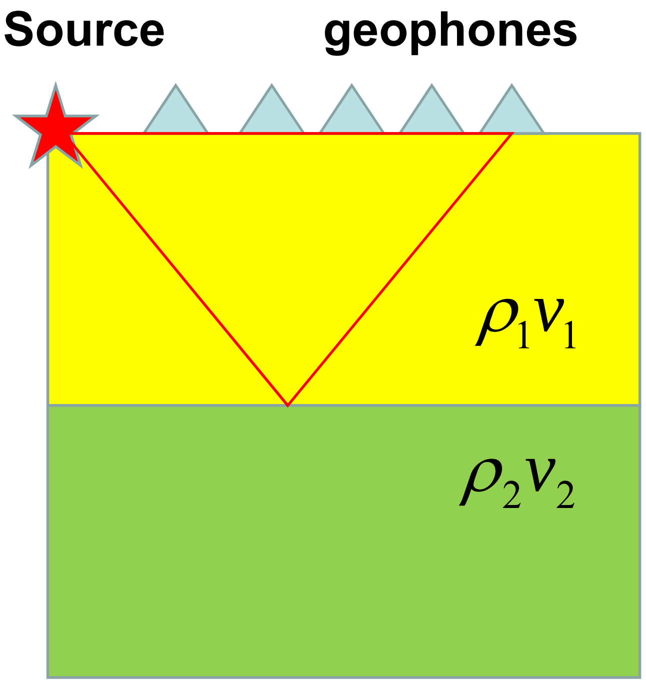
• If Z1 = Z2, there is no reflection. All energy is transmitted into the second layer. This does not mean that ρ1=ρ2 and v1= v2! All that matters is that $\boldsymbol{\rho_1 v_1 = \rho_2 v_2}$

• **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

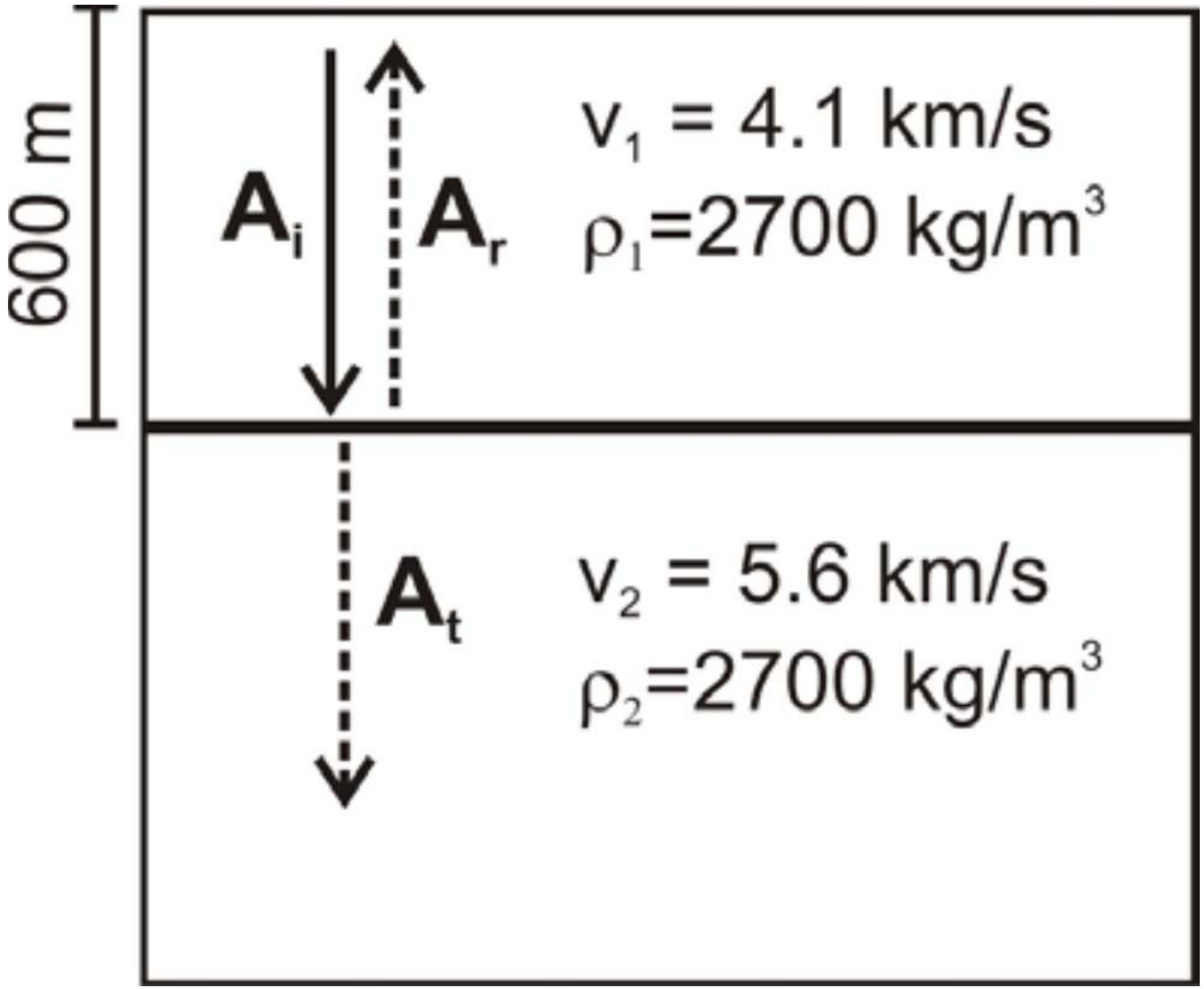
Case 1: An increase in velocity with depth

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 (Ar and At) can be calculated from the Zoeppritz equations. Assume that Ai = 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?


600 m
A_i
A_r
v_1 = 4.1 km/s
ρ_1=2700 kg/m^3
A_t
v_2 = 5.6 km/s
ρ_2=2700 kg/m^3

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

$$Z1 = \rho_1 v_1 = 2700 \times 4.1 = 11{,}070 \ (\text{kg km s}^{-1}\ \text{m}^{-3})$$

$$Z2 = \rho 2 v2 = 2700 \times 5.6 = 15{,}120 \ (\text{kg km s}^{-1}\ \text{m}^{-3})$$

b) R and T:

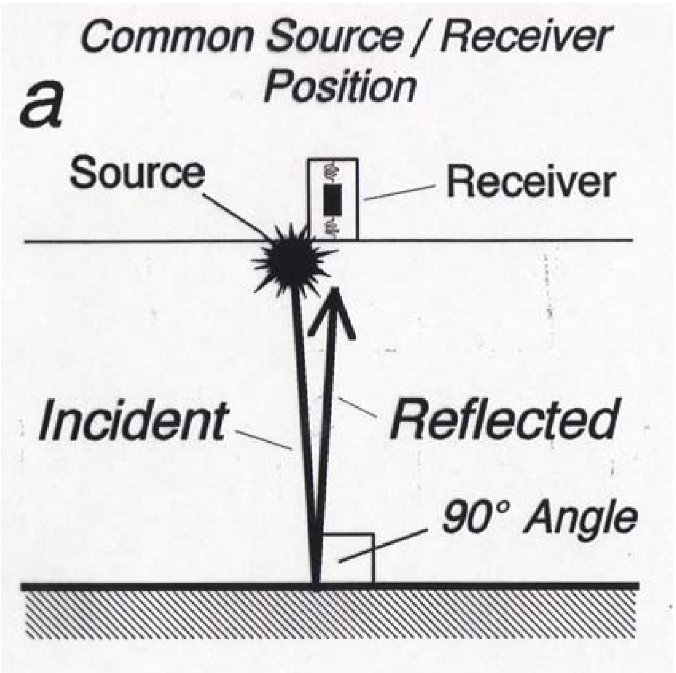
The reflection and transmission coefficients are then:

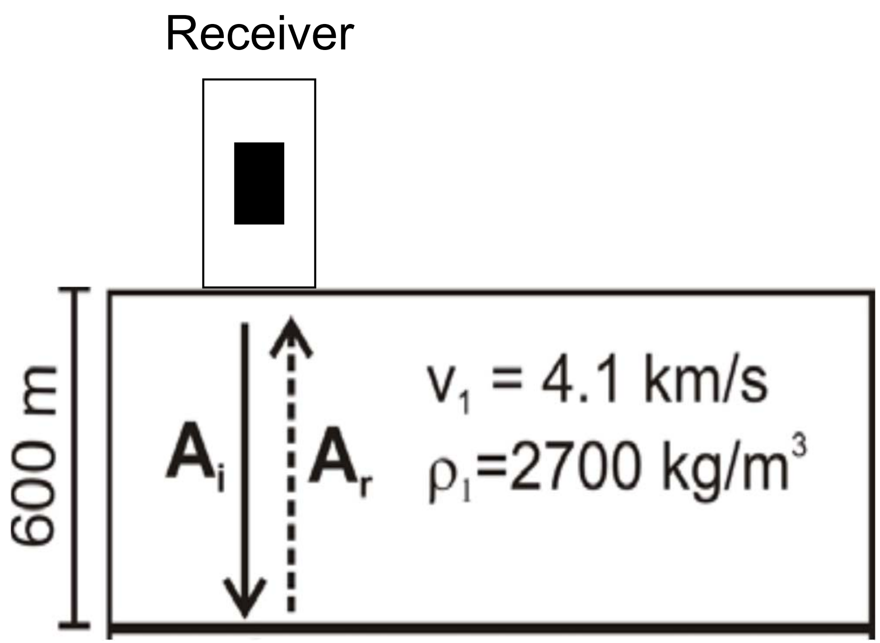
$$R = 0.15 \ , \quad T = 0.85$$

c) The amplitude of the two waves:

$$A_r = R \times A_i = 0.15 \qquad A_t = T \times A_i = 0.85$$

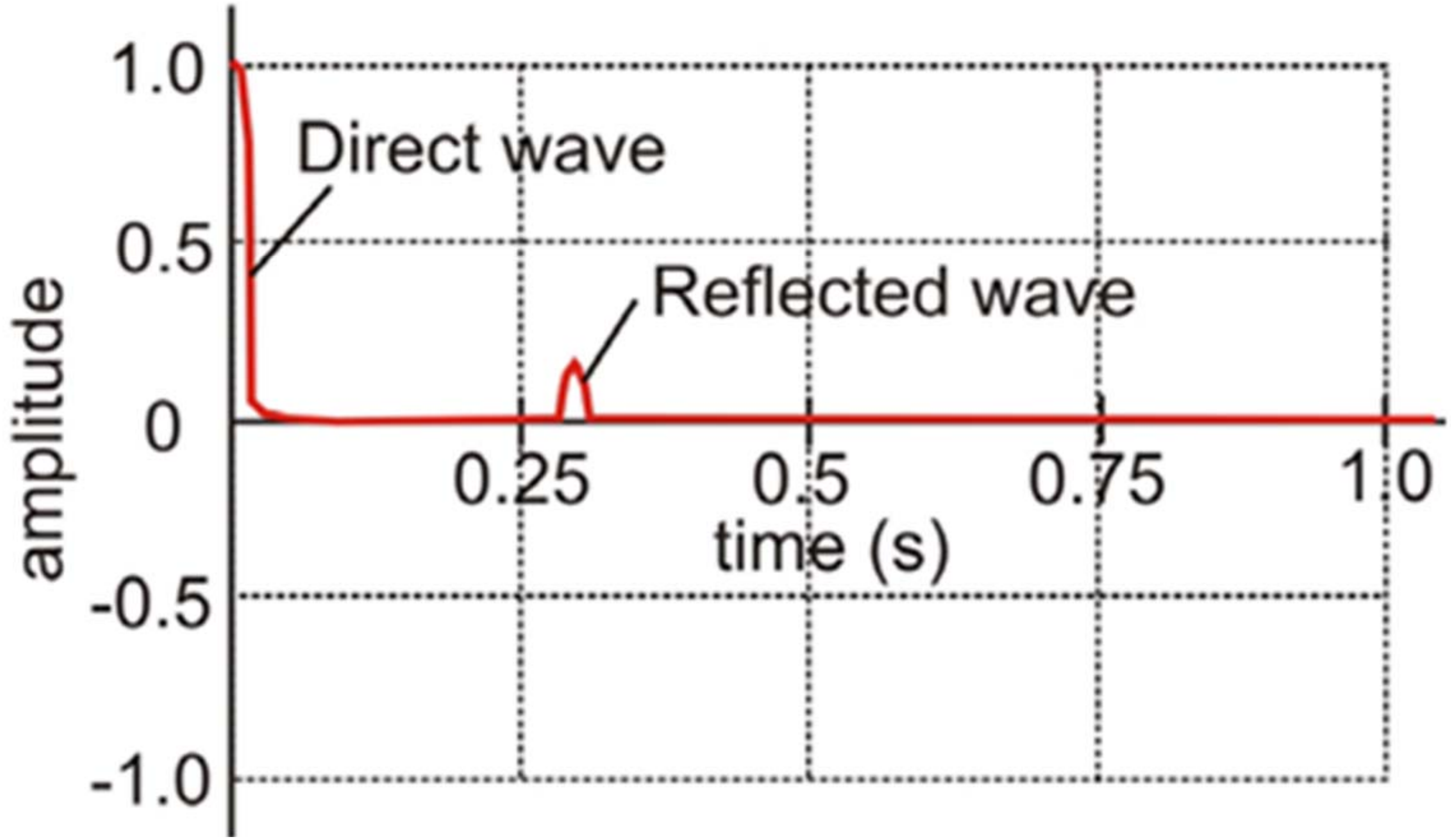
Q. Calculate the arrival time for the wave?





Time = 2 x 600 / 4100 = 0.29s

The seismic record will look like this:

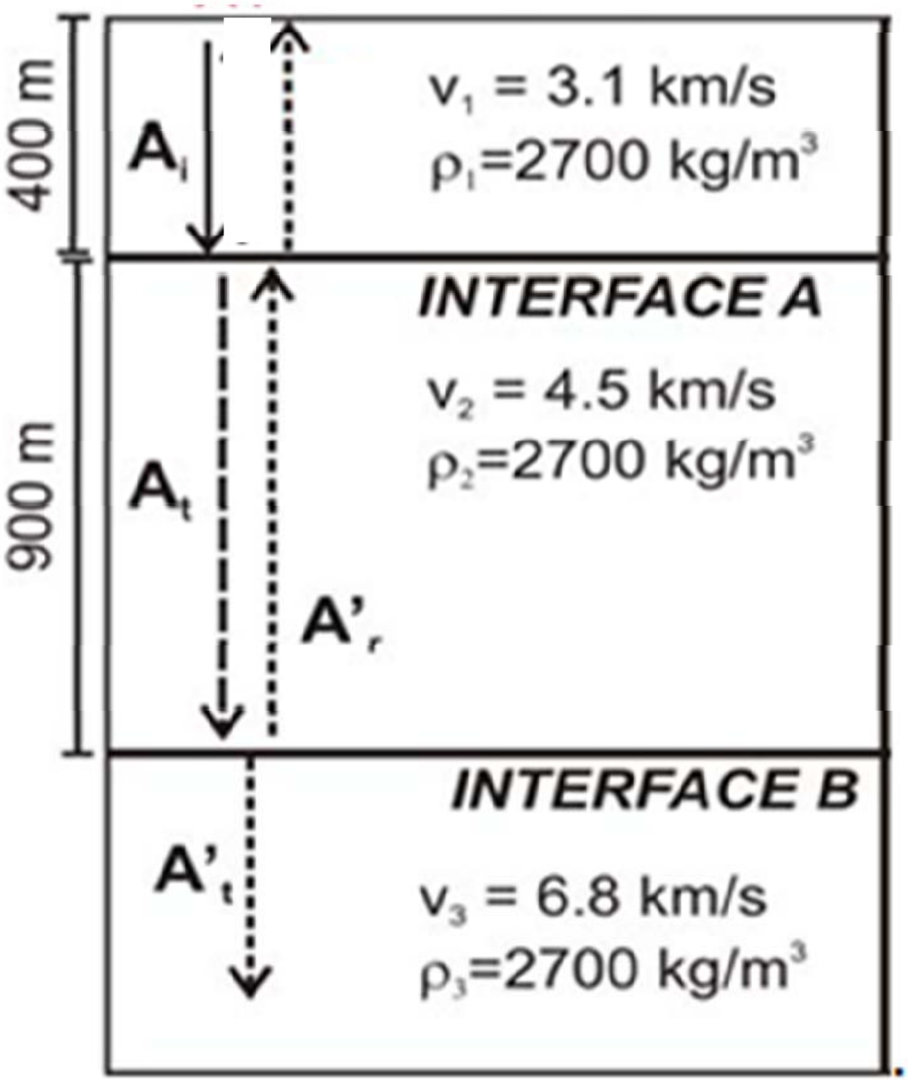


Calculate:

a) R and T for interface A

b) R and T for interface B

c) Total arrival time



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

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

R_A= 0.18 and T_A= 0.82

Arrival time for interface A= 0.26 sec

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

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

R_B= 0.20 and T_B= 0.80

Arrival time for interface B = 0.4 sec

c) Total arrival time = 0.26 + 0.4 = 0.66 sec