Physics 3 – Fall 2016

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PSR 1019 Broida

TEXTBOOK IS UNIVERSITY PHYSICS 14TH ED

Grading Policy

Attendance in lecture and lab is important

Homework – ~ weekly - do it yourself – DO NOT COPY – 20%

Midterm(s) one or two depending on class 30%

Final 50%

TA's –

CLAS:

Labs – Broida 3324

See Jean Dill in the Physics Office if you have lab issues

Physics 3 - Chapter 15

Mechanical waves and oscillations

What types of waves can you think of?

Water waves (surface “gravity waves”) - surfing

Acoustical waves in air, water, metal etc -> radiates ***phonons***

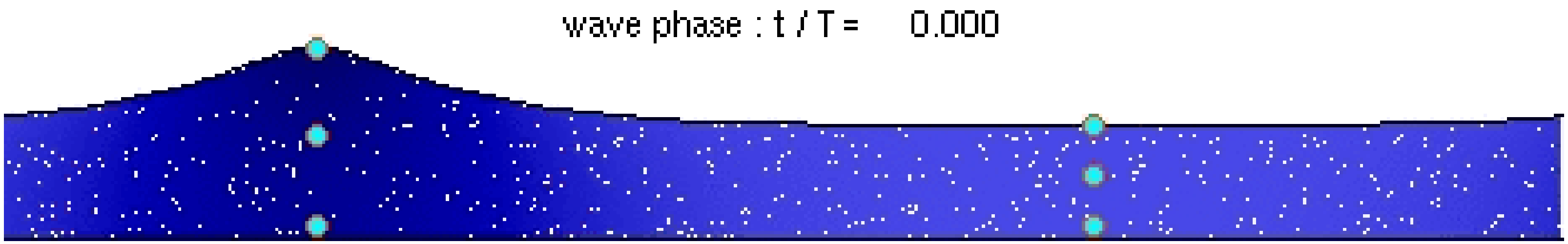
Shock waves – “sonic boom” – Space Shuttle entry into atmos

Electromagnetic waves -> radiates ***photons***

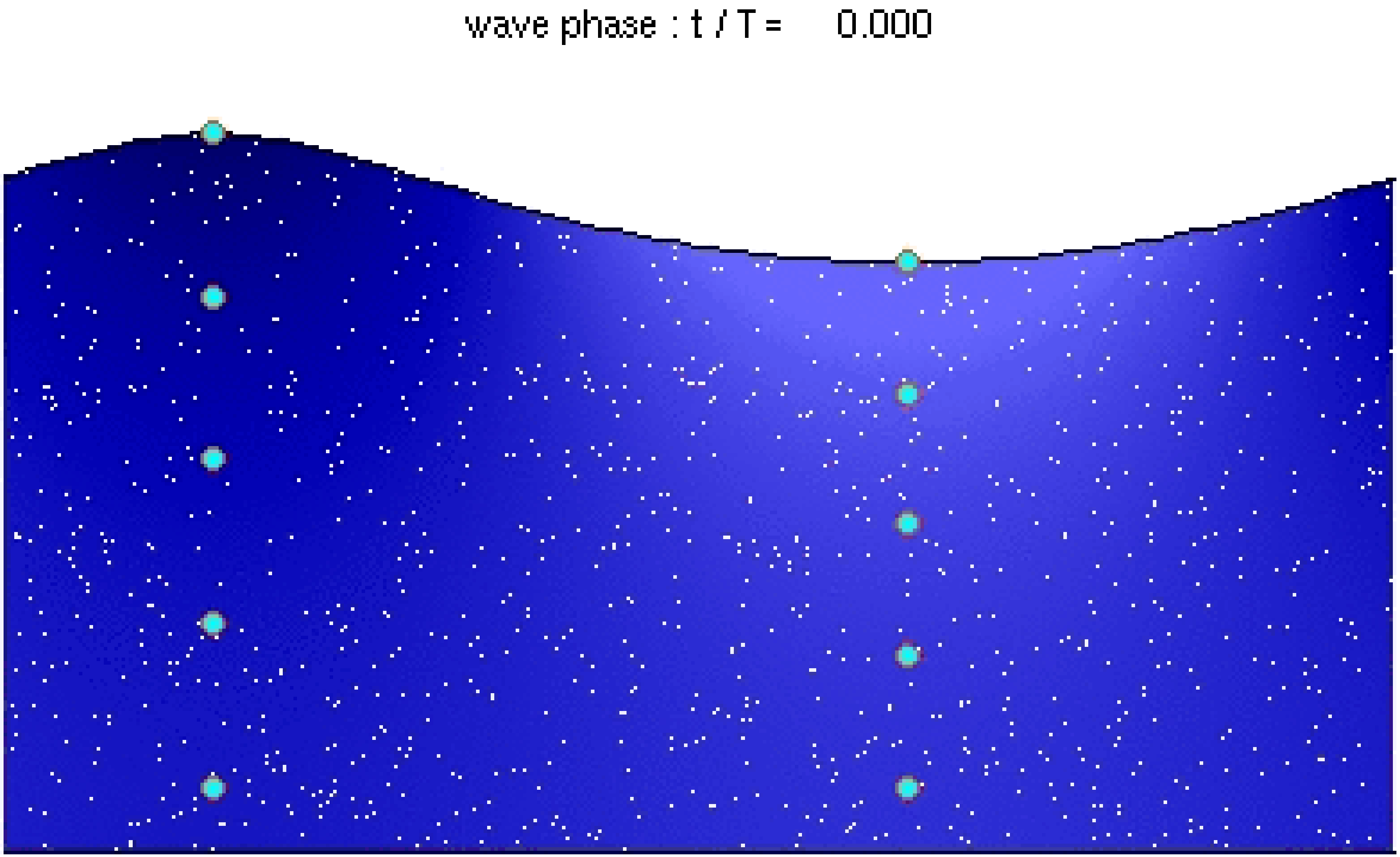
Gravity waves – accelerating mass -> radiates ***gravitons***

Matter waves – wave particle duality – linear momentum -> ***matter wave*** – basis for our understanding of “Quantum Mechanics”

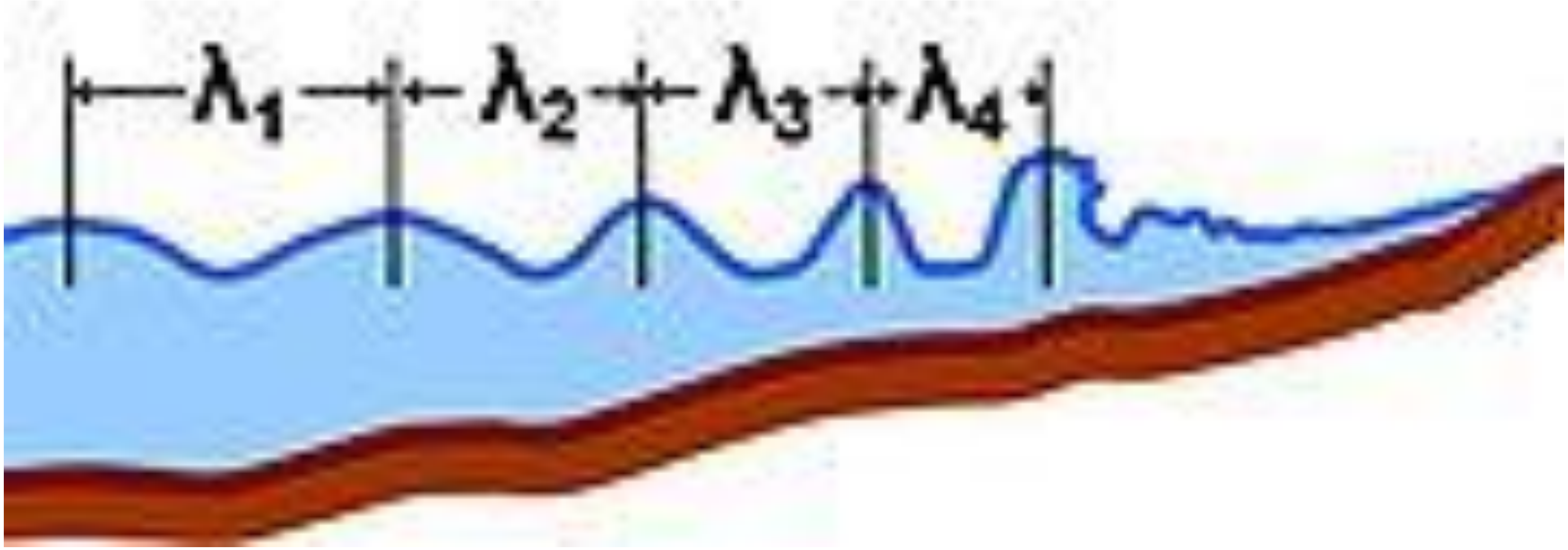
Shallow water “gravity wave”



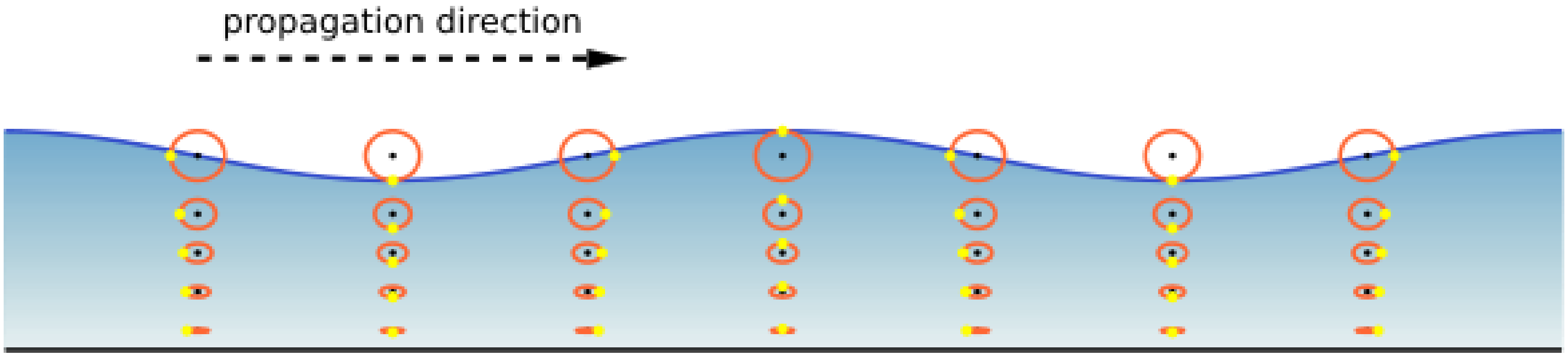
Deep water "gravity wave"



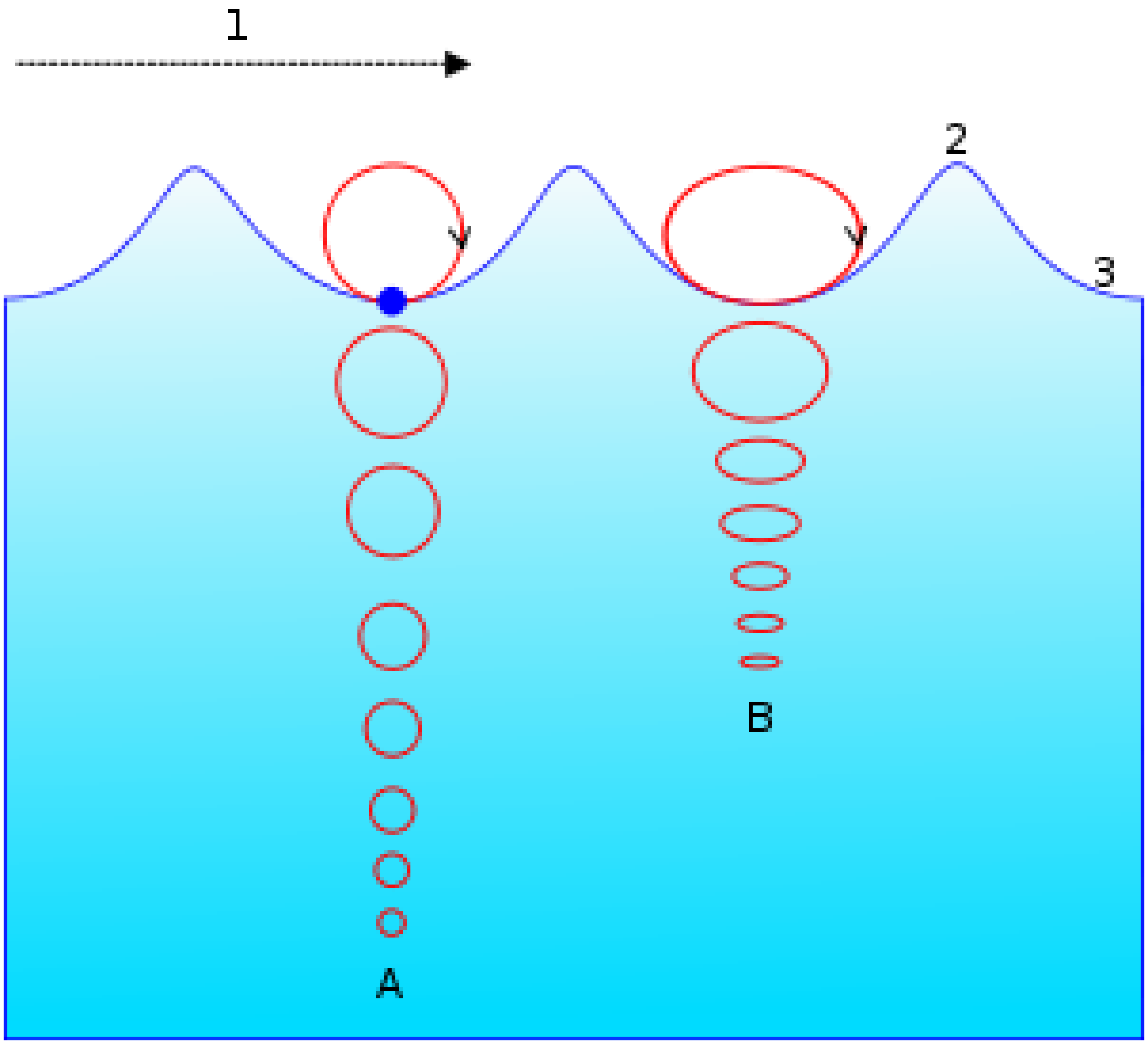
A breaking water wave



Gentle water wave particles execute near circular motion



In shallow larger amplitude waves particle motion becomes elliptical



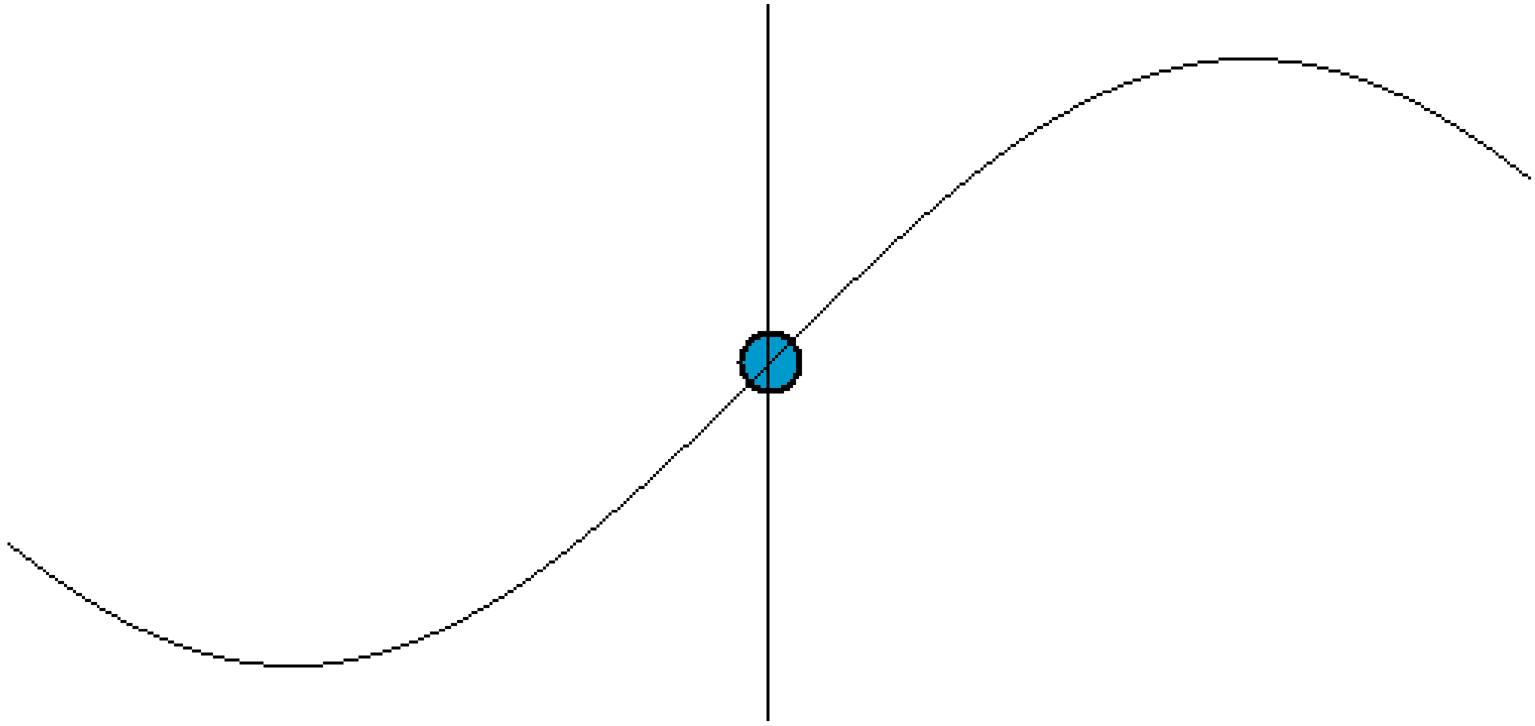
Simple Harmonic Motion (Oscillation) $y(t)=A*\sin(\omega t+\phi)$

ω=angular freq (radians/sec)

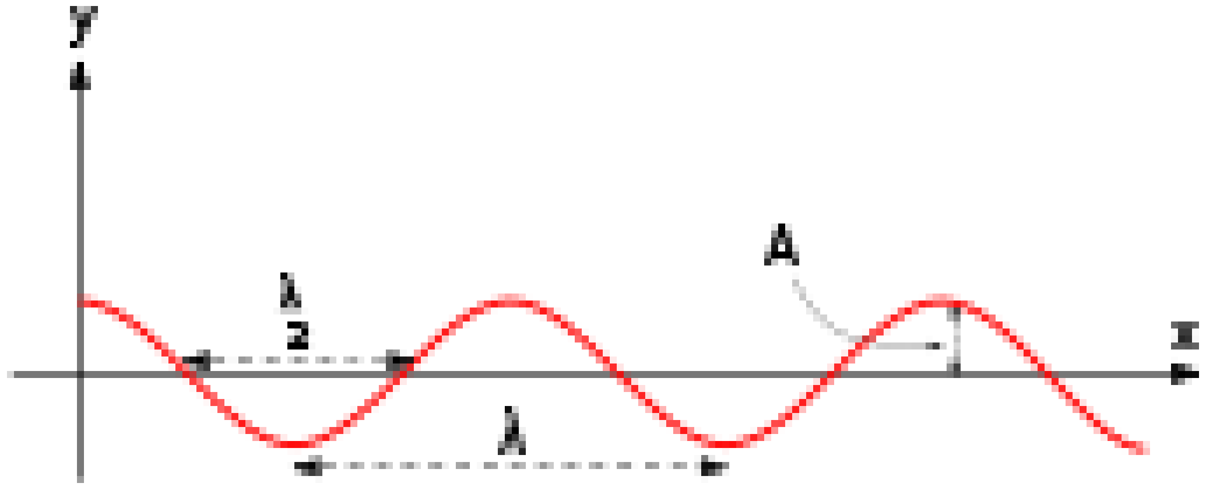
t=time

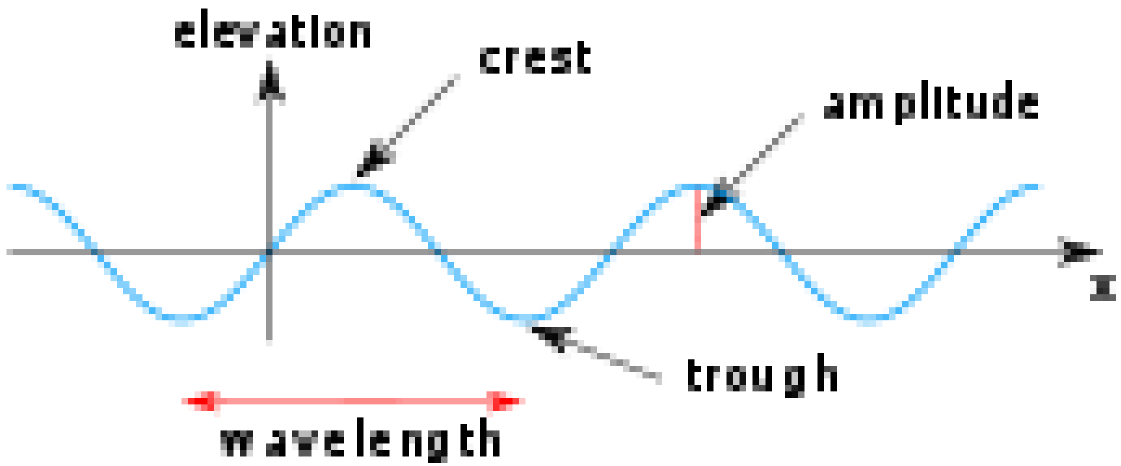
ϕ=Phase shift (angular – radians)

A=Amplitude



Wave notation





Frequency=f, Period=T, Angular freq=ω Wavelength=λ Wave number=k

$$f = \frac{1}{T}. \qquad \omega = 2\pi f = \frac{2\pi}{T}.$$

$$k = \frac{2\pi}{\lambda}.$$

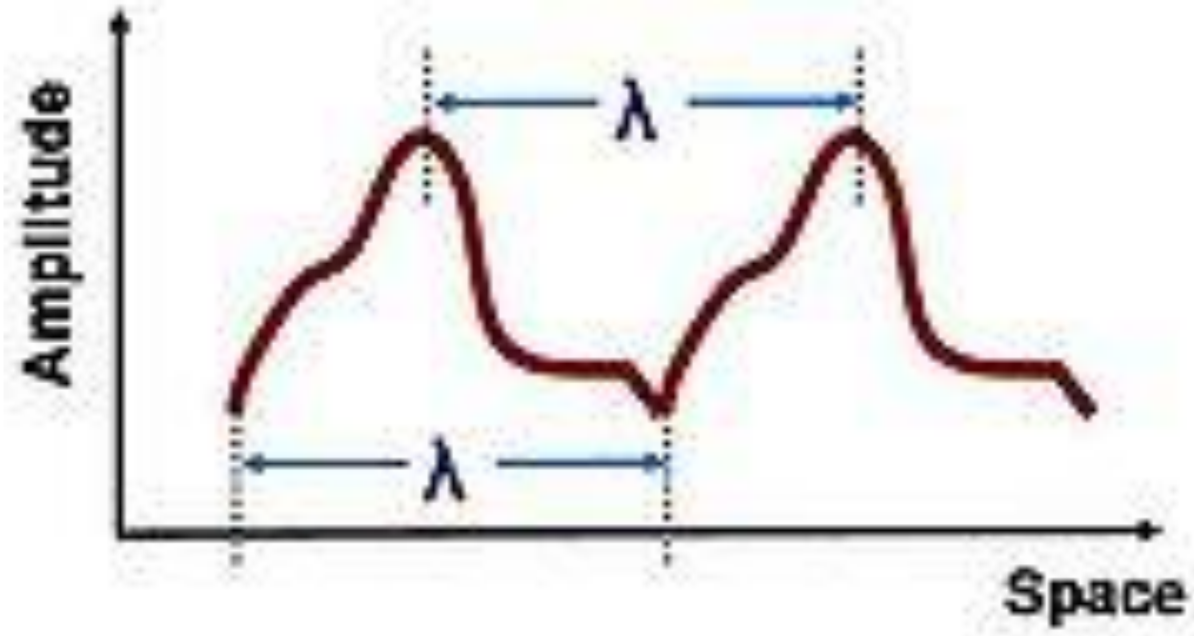
For a purely sinusoidal wave the wavelength and frequency are inversely related

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

ω=v*k

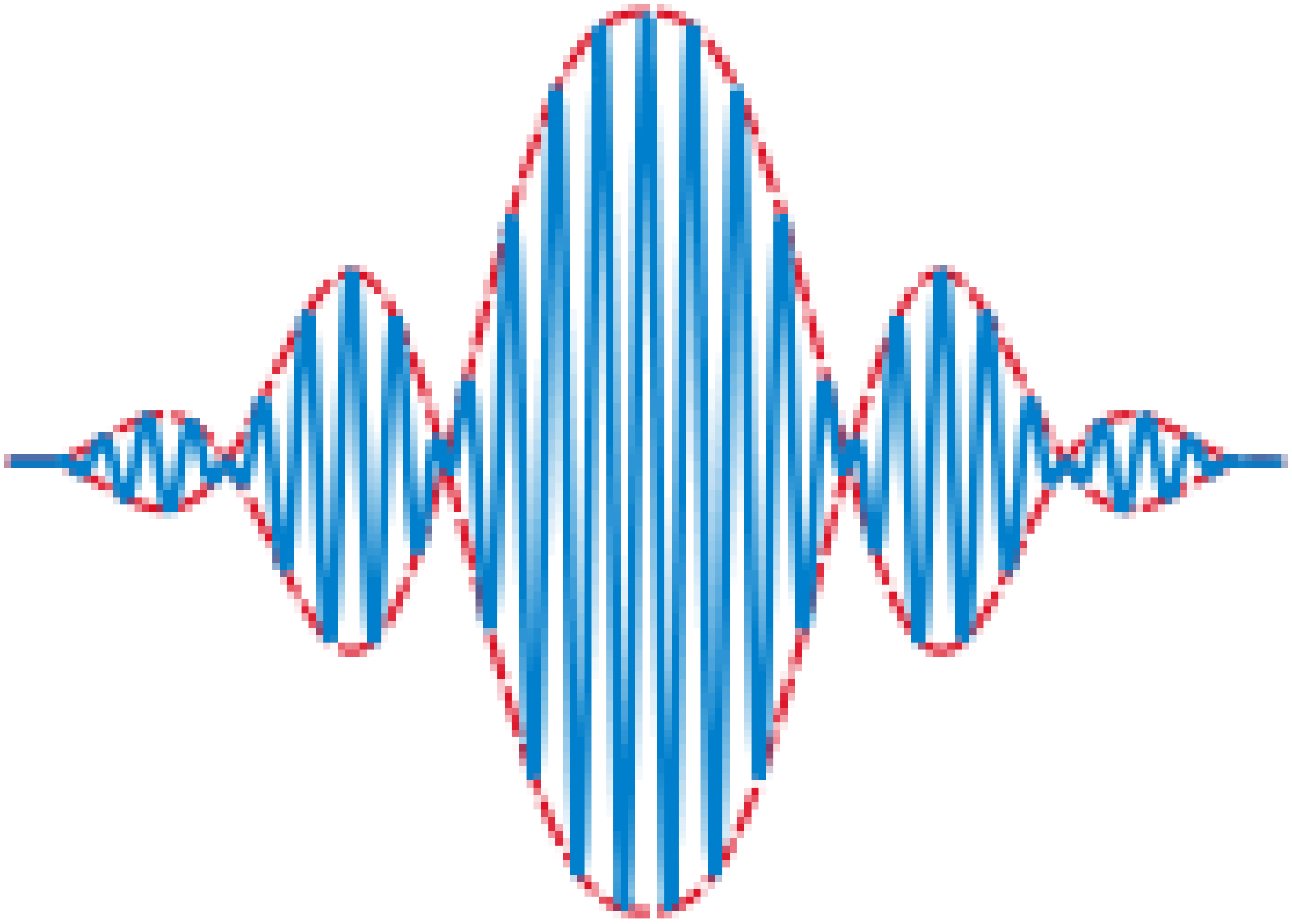
dispersion relation

Not all waves are sinusoidal – normally they are periodic hence have a specific wavelength

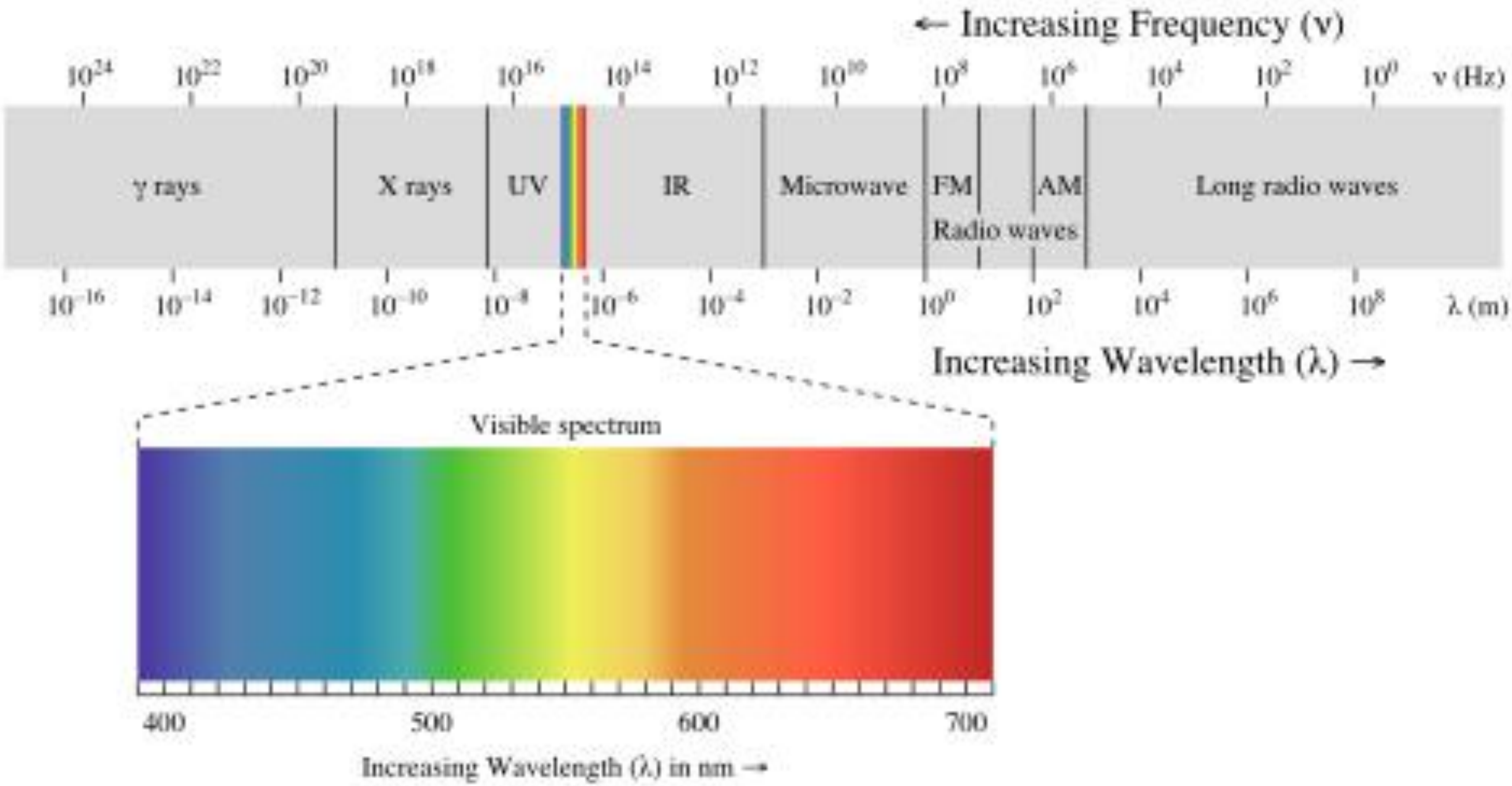


Wave can add and we get packets of waves

We call this a Wave Packet



Other waves – Electromagnetic Waves

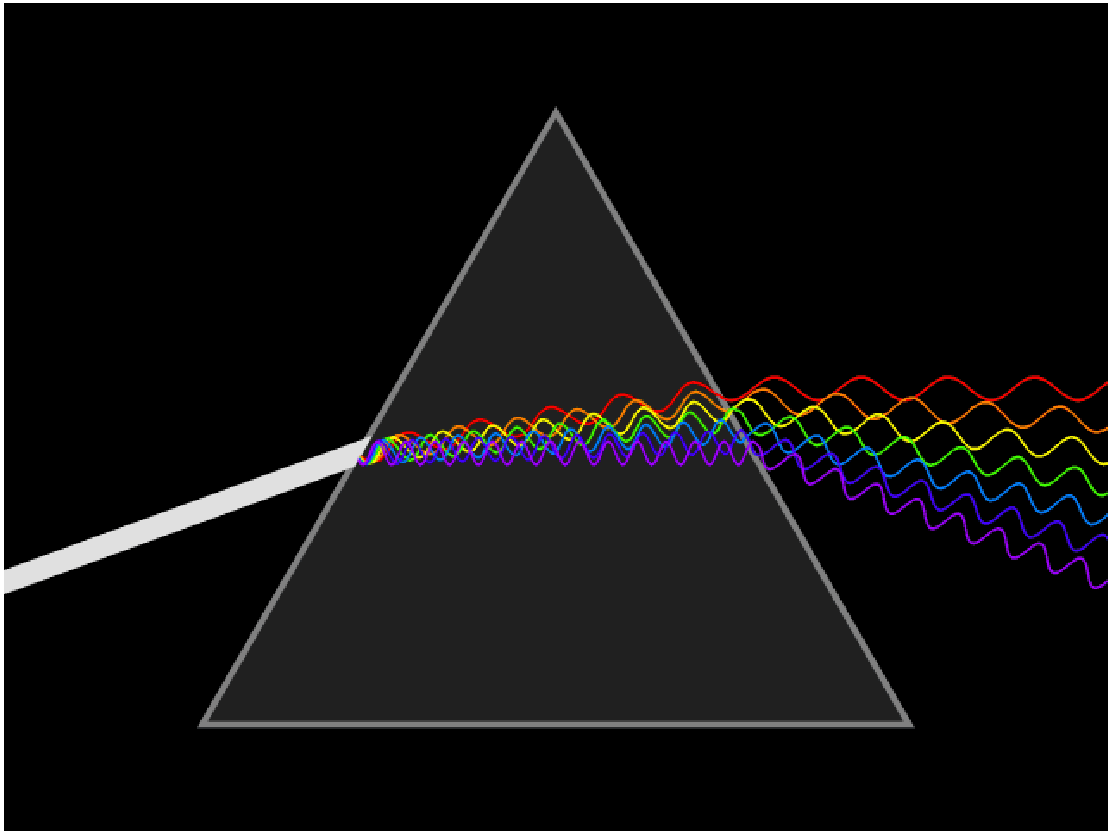


Dispersion happens when different wavelengths travel at different speeds – Prism example

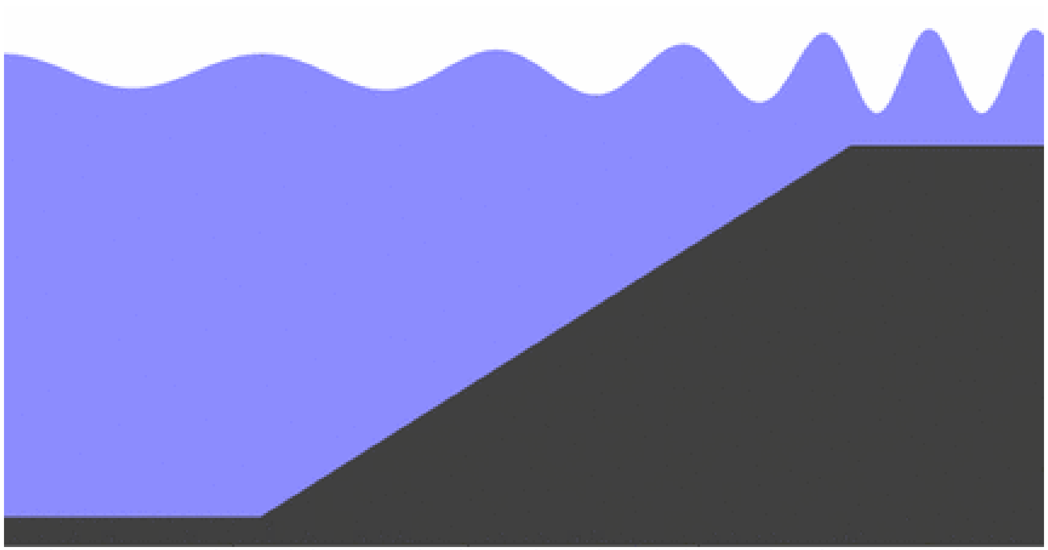
Dispersion can also happen in non-linear waves

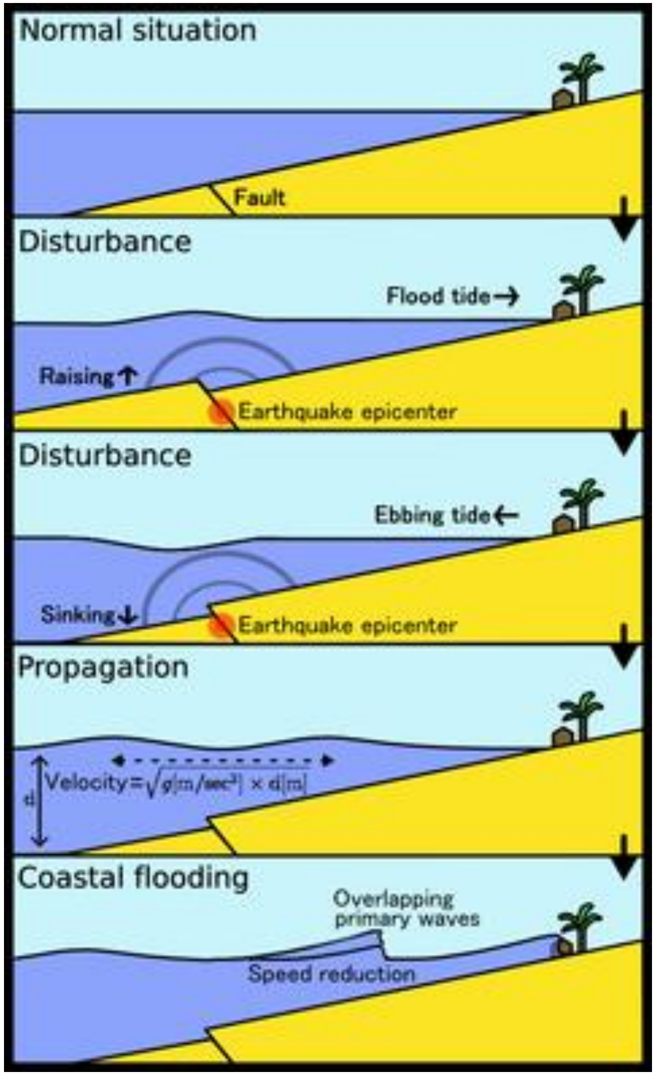
Wave speed then depends on amplitude

Example - water waves – “surfing, tsunami..”



As wave enters shallow bottom is slows and the amplitude increases





Tsunami generated by fault slip and volcano

Thailand 12/26/04 – More than 300,000 killed

Large Tsunamis can have speeds exceeding 500 MPH!!

An asteroid hit in the ocean could be supersonic

Samoan Tsunami Sept 2009

Group speed vs phase speed

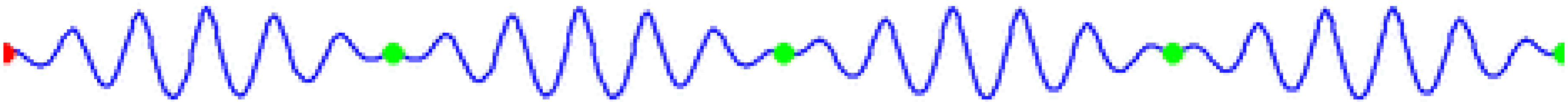
Red is phase Green is group

Phase speed tracks a given phase (any)

Group speed track the group packet speed

$v_p = \omega / k$ $\qquad$ $v_g = d\omega/dk$

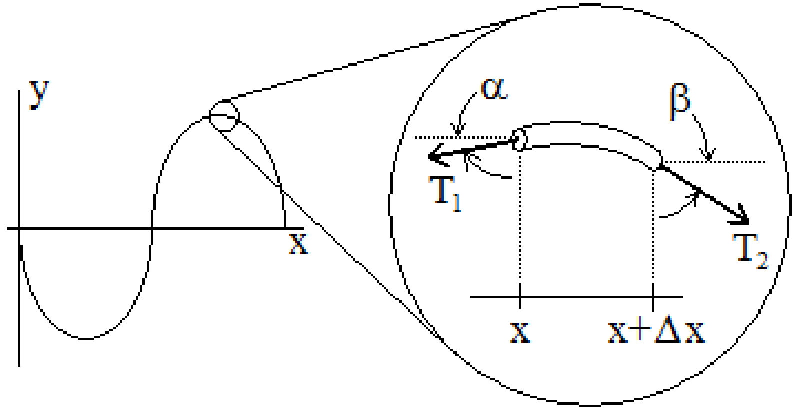
$v_p \geq v_g$



Standing waves have fixed boundary conditions

A piano and a guitar are examples

String (wire) under tension (T) [μ =mass/length]



$$T_{1x} = T_1\cos(\alpha) \approx T_{2x} = T_2\cos(\beta) \approx T.$$

$$\Sigma F_y = T_{2y} - T_{1y} = T_2\sin(\beta) - T_1\sin(\alpha) = \Delta m a \approx \mu\Delta x\frac{\partial^2 y}{\partial t^2}.$$

$$\frac{\mu\Delta x}{T}\frac{\partial^2 y}{\partial t^2} = \frac{T_2\sin(\beta)}{T_2\cos(\beta)} - \frac{T_1\sin(\alpha)}{T_1\cos(\alpha)} = \tan(\beta) - \tan(\alpha)$$

$$\frac{1}{\Delta x}\left(\left.\frac{\partial y}{\partial x}\right|^{x+\Delta x} - \left.\frac{\partial y}{\partial x}\right|^{x}\right) = \frac{\mu}{T}\frac{\partial^2 y}{\partial t^2}$$

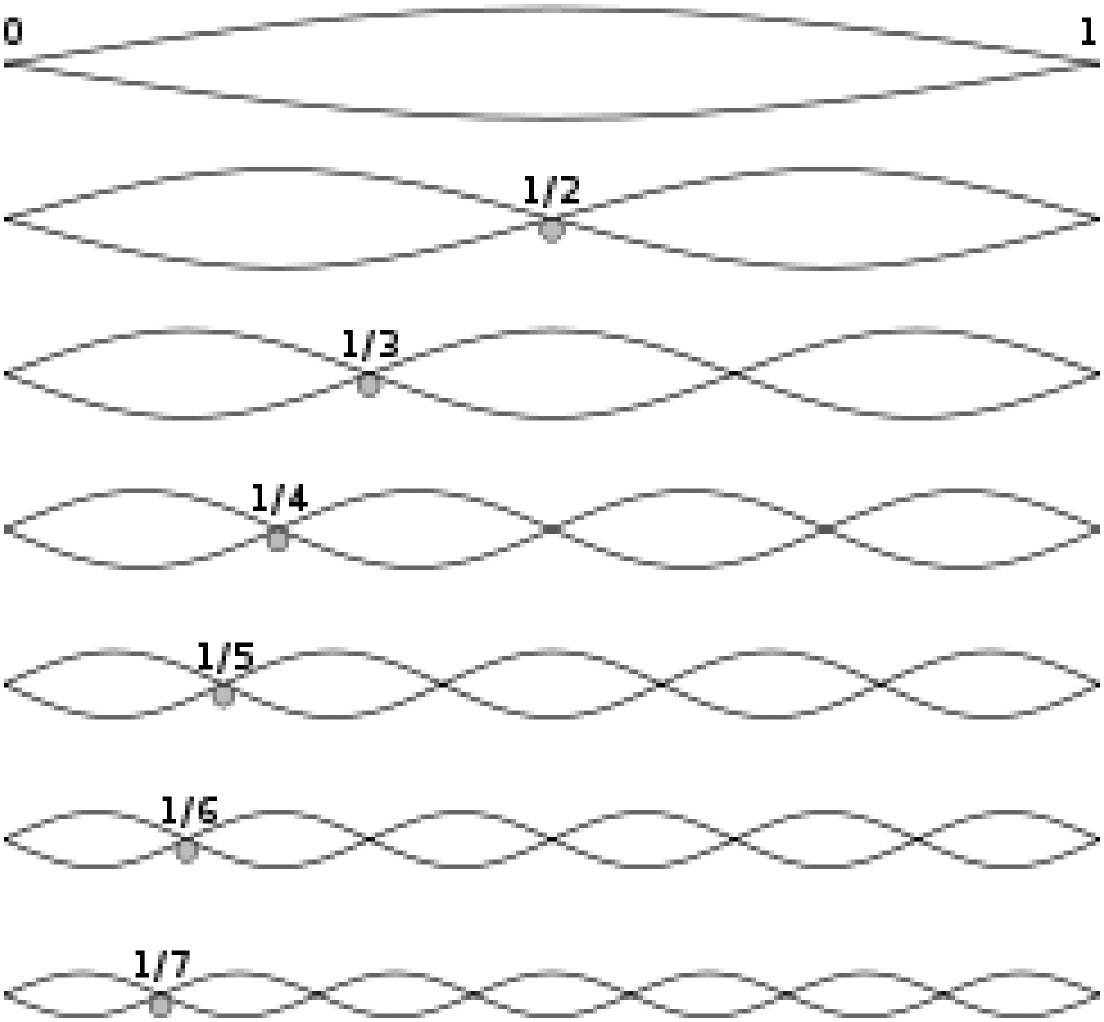
Equation of tensioned wire

- 2nd order linear diff eq – simple sin, cos solution
- y=A*sin (or cos) (x+-vt)
- Use Fourier transform to get any solution

$$\frac{\partial^2 y}{\partial x^2} = \frac{\mu}{T}\frac{\partial^2 y}{\partial t^2}.$$

$$v = \sqrt{\frac{T}{\mu}},$$

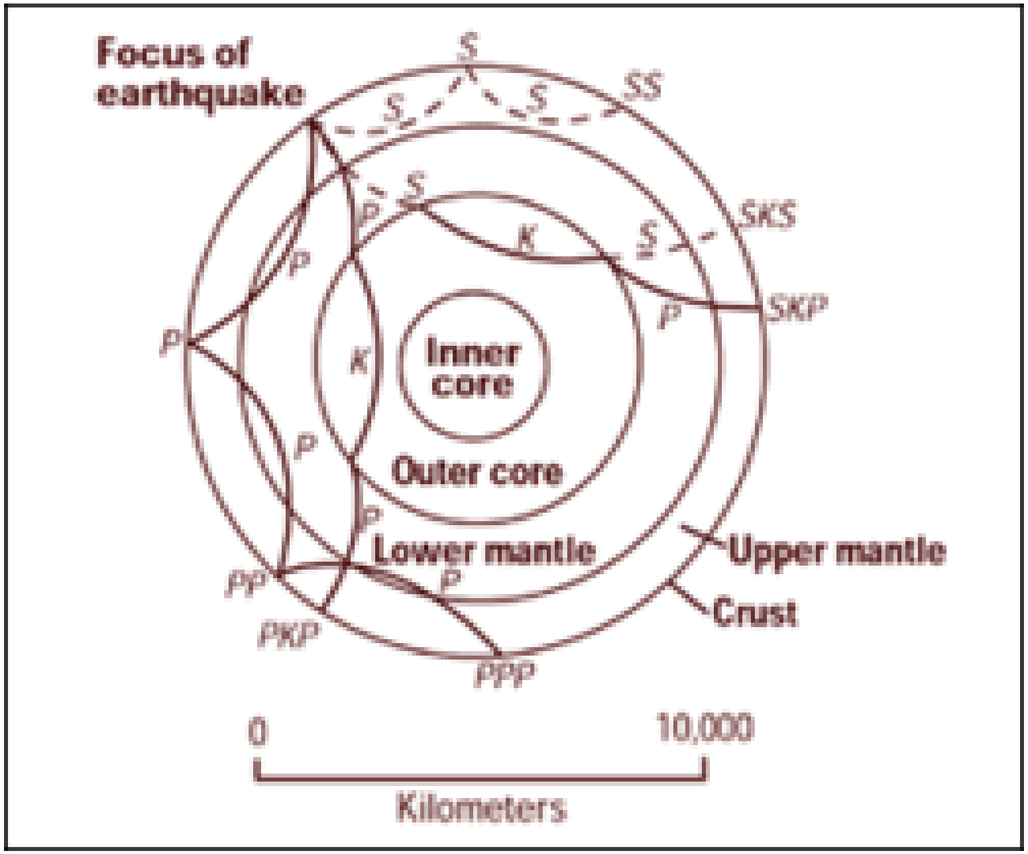
Standing Waves on a string
Fundamental and 6 harmonics
Such studies date back to Ancient Chinese ~3000BC

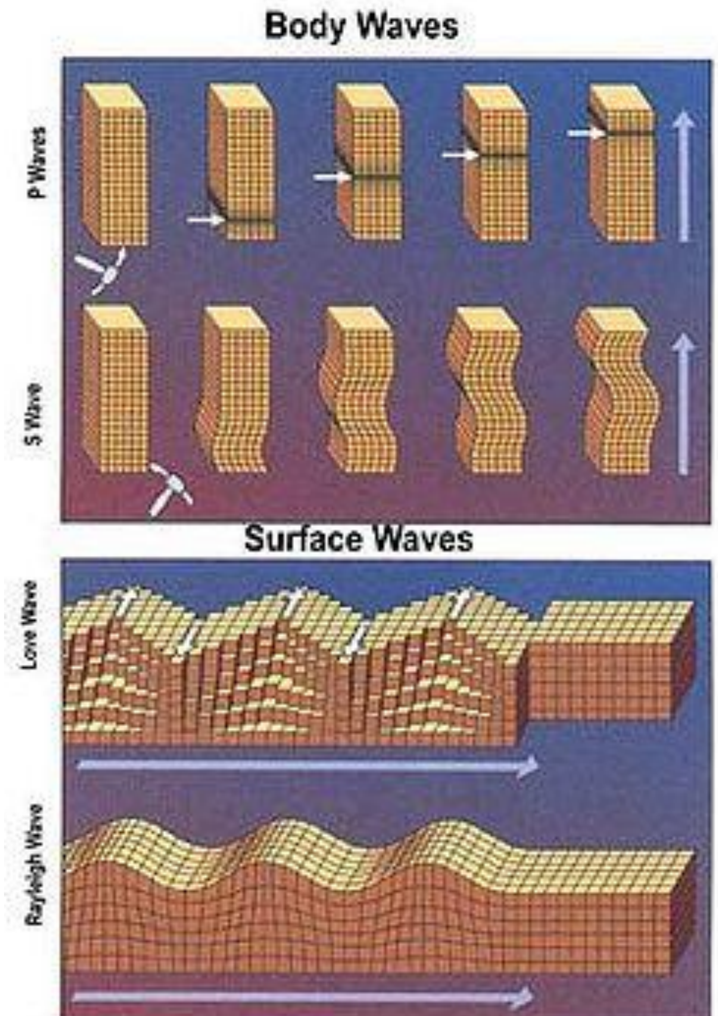


Body and Surface waves in the earth

S – "Secondary" transverse shear wave

P – "Primary" longitudinal compressional wave





S and P waves – body waves

P (longitudinal- compression) waves travel in solids, liquids and gases

S (transverse) waves travel in solids or gels only

In earthquake S waves are most destructive

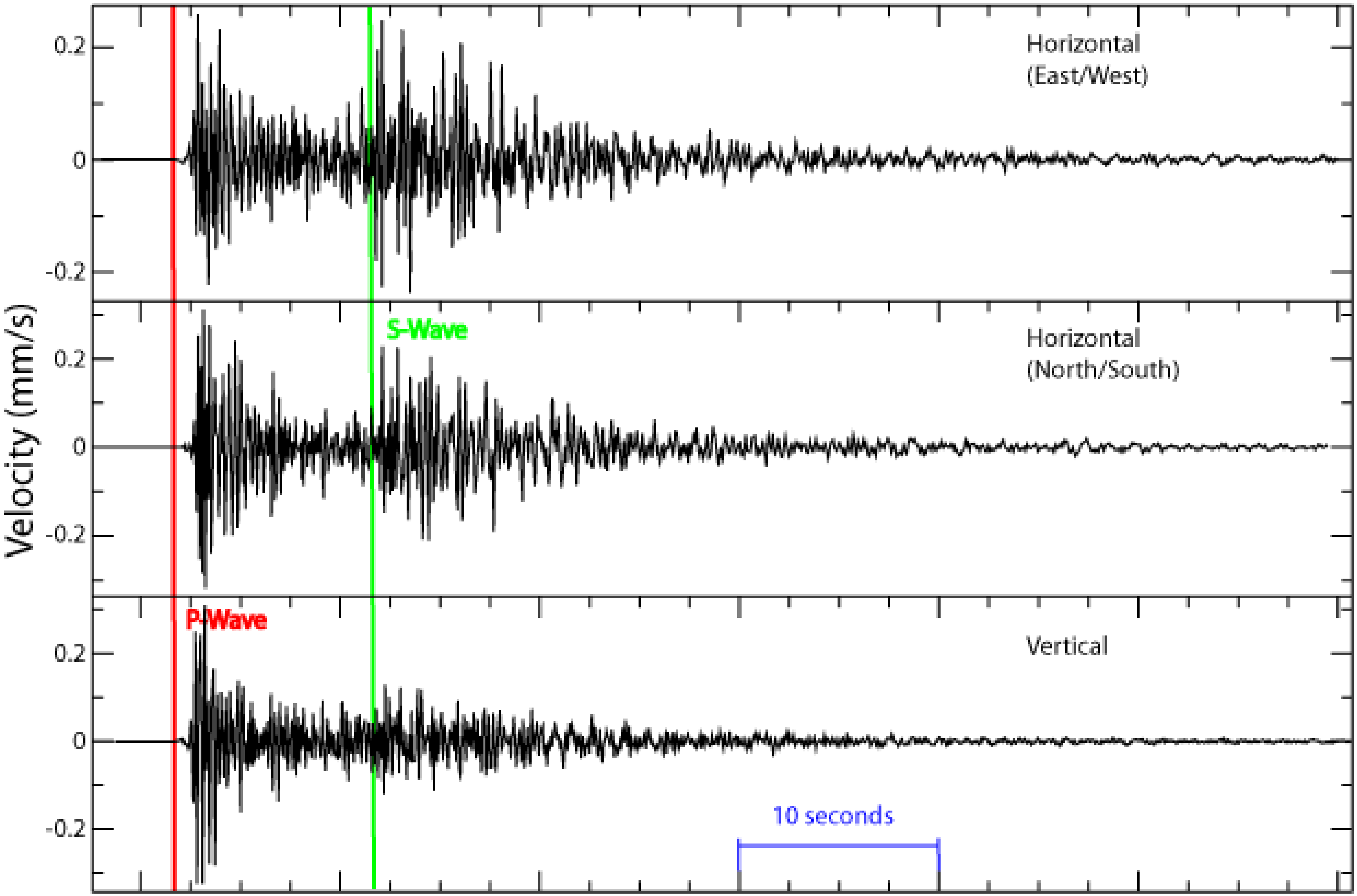
P waves travel faster hence arrive first

S waves travel about 50-60% speed of P

Typ depth of earthquake ~ 40 Km but some >700

Timing of S and P gives location of epicenter

Timing of S and P wave



Surface Waves

Surface waves generally travel much slower

But can be extremely destructive

Rayleigh and Love are the two common types

Rayleigh – “rolling wave” ~ 90% speed of S

Love – horizontal shear wave ~ 90% speed of S

Earthquake metric – Richter scale

Richter magnitudes	Description	Earthquake effects	Frequency of occurrence
Less than 2.0	Micro	Microearthquakes, not felt.	About 8,000 per day
2.0-2.9	Minor	Generally not felt, but recorded.	About 1,000 per day
3.0-3.9		Often felt, but rarely causes damage.	49,000 per year (est.)
4.0-4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	6,200 per year (est.)
5.0-5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	800 per year
6.0-6.9	Strong	Can be destructive in areas up to about 160 kilometres (100 mi) across in populated areas.	120 per year
7.0-7.9	Major	Can cause serious damage over larger areas.	18 per year
8.0-8.9	Great	Can cause serious damage in areas several hundred miles across.	1 per year
9.0-9.9		Devastating in areas several thousand miles across.	1 per 20 years
10.0+	Epic	Never recorded	Extremely rare (Unknown)

Richter Scale and Moment Magnitude Scale

Charles Richter and Beno Gutenberg – 1935 Caltech

Studying S. Cal earthquakes defined a logarithmic scale

Difference of 1 corresponds to a factor of 10 in displacement

Energy release scales as ~ 3/2 power of displacement

Difference of 1 = $(10)^{3/2}$ ~32 in energy, diff of 2 =1000 energy

Zero point was set by 1 micron displacement of Wood-Anderson torsion seismometer 100 Km from quake

Negative values are possible with modern seismometers

No upper limit

Mag 10 is extremely destructive

Some historical examples

Nov 1, 1755   Lisbon M~8.7 80,000 killed – huge Tsunami follows

Feb 28, 1870 Iran M ~ 7.4 200,000 killed

Nov 25, 1833 Sumatra M ~ 9.2 – Large number of victims – huge Tsunami

Jan 23, 1855 Wairapa, New Zealand M~8 4 killed – raised coast by 2 m!

Mar 26, 1872 Lone Pine, CA M ~ 7.3 27 killed

Sept 1, 1888 N. Canterbury, NZ M ~ 7.3 – first quake with mainly horizontal fault

June 15, 1896 Iwate Japan M ~ 8 22,000+ killed

Apr 18, 1906 San Fransisco M ~ 7.8 3000 killed

June 29, 1925 Santa Barbara M ~ 6.8 13 killed – mission destroyed

Mar 28, 1964 Alaska M ~ 9.2 131 killed

Feb 9, 1971 San Fernando Valley, CA M ~ 6.6   65 killed

Oct 17, 1989 Loma Prieta – Bay Bridge collapses M ~ 7 63 killed

Jan 17, 1994 Northridge, CA M ~ 6.7 60 killed

Earthquakes and Nuclear testing

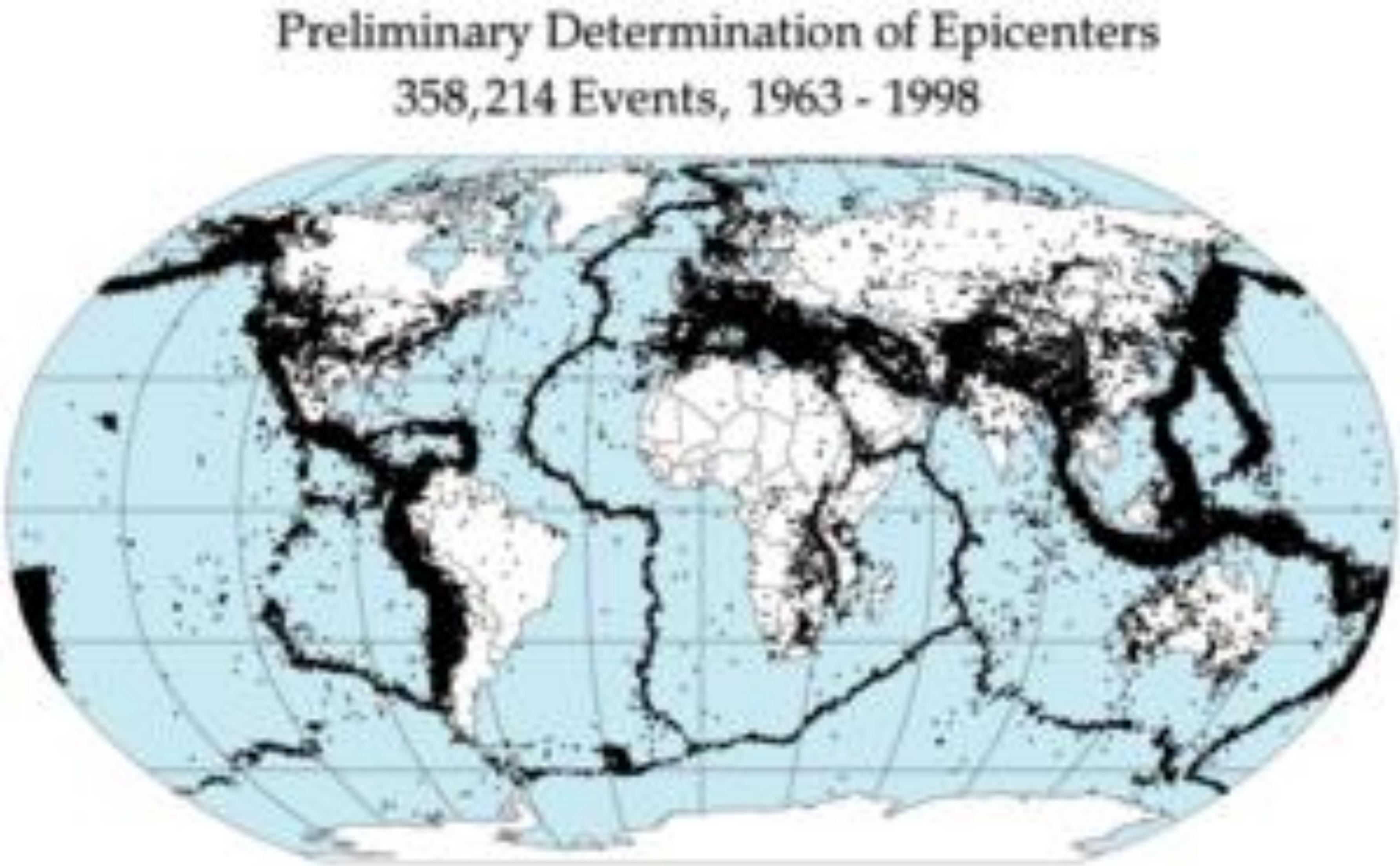
$$M_{\mathrm{n}} = \frac{2}{3}\log_{10}\frac{m_{\mathrm{TNT}}}{\mathrm{Mt}} + 6$$

m_{TNT} is the yield in MegaTons (MT) – TNT equivalent
1 Ton TNT (trinitrotoluene) ~ 10^9 calories ~ 4×10^9 Joules
Largest US underground test was ~ 5MT
Codenamed Cannikin on Nov 6, 1971 in the Aleutian Islands
For 5 MT this would yield about M ~ 6.5
Note – 1 KiloTon (1 KT) M ~ 4
0.5-1% of yield goes into earthquake energy
1 Kg matter annilation ~ 1 MT
Do nuclear tests trigger earthquakes?
No evidence to support this
(http://earthquake.usgs.gov/learn/faq/?categoryID=12&faqID=88)

Some local earthquakes

- Northridge Earthquake 1971 ->
- Loma Prieta Oct 1989 others

Earthquakes are not uniformly distributed



Body waves can be used for exploration – oil, etc

Example below is explosive driven wave to look for land mines