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# Physics 3 – Winter 2010

Professor Philip Lubin

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Office hours: 9:15-10 after class

Website – [www.deepspace.ucsb.edu](http://www.deepspace.ucsb.edu) Classes

PSR 1019 Broida

[http://www.physics.ucsb.edu/Education/plc\\_office\\_hrs.php3](http://www.physics.ucsb.edu/Education/plc_office_hrs.php3)

**TEXTBOOK IS UNIVERSITY PHYSICS 12<sup>TH</sup> ED**

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# 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 – Ron Ferril (ron@physics..), Amit Vainsencher (amit@physics...)

Labs – Broida 3324 W 4-6:50 (Ron Ferril) T 1-4? (Amit Vainsencher)

TA Office hours (PSR) Ron M 4:30-5, F 1:30-2:30 Amit Th 11:30-1

<http://physics.ucsb.edu/~labsched/winter2010/winter3l.pdf>

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

# Physics 3 - Chapter 15

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## 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***

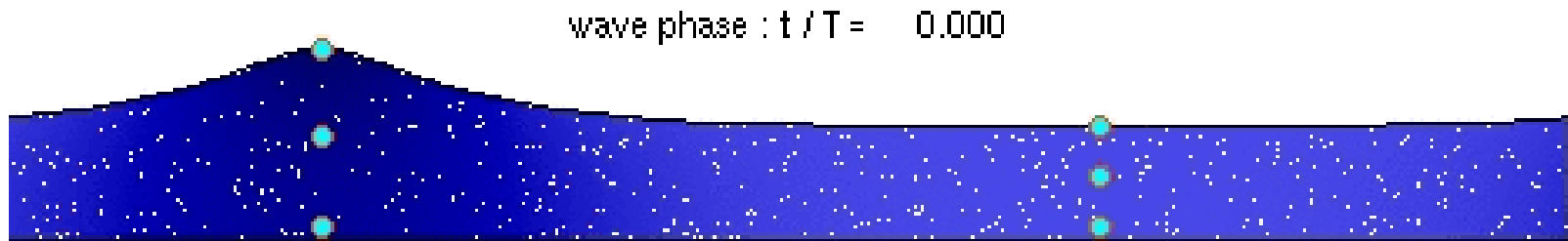
Matter waves – wave particle duality – linear momentum -> ***matter wave*** – basis for our understanding of “Quantum Mechanics”





# Shallow water “gravity wave”

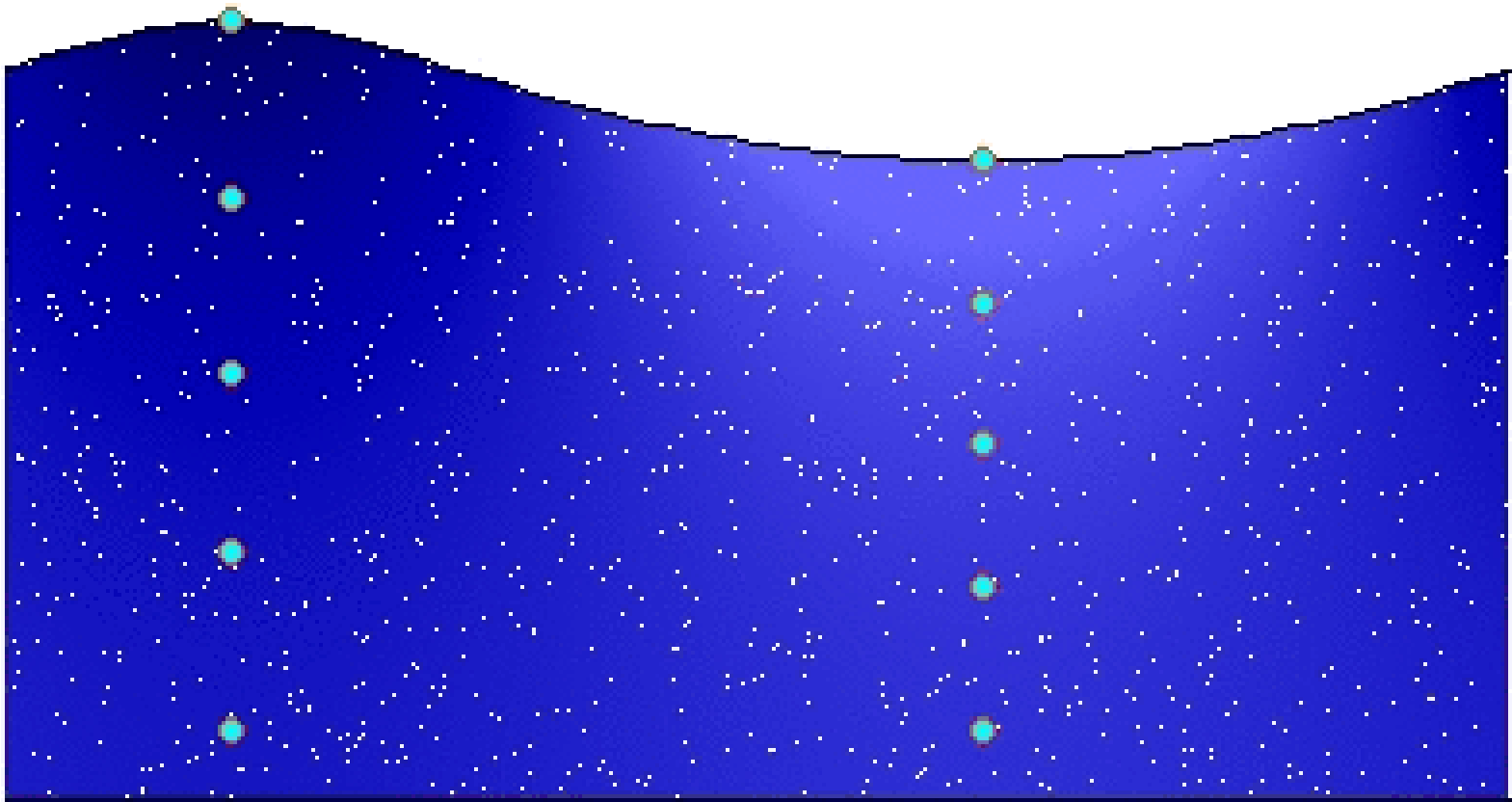
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# Deep water “gravity wave”

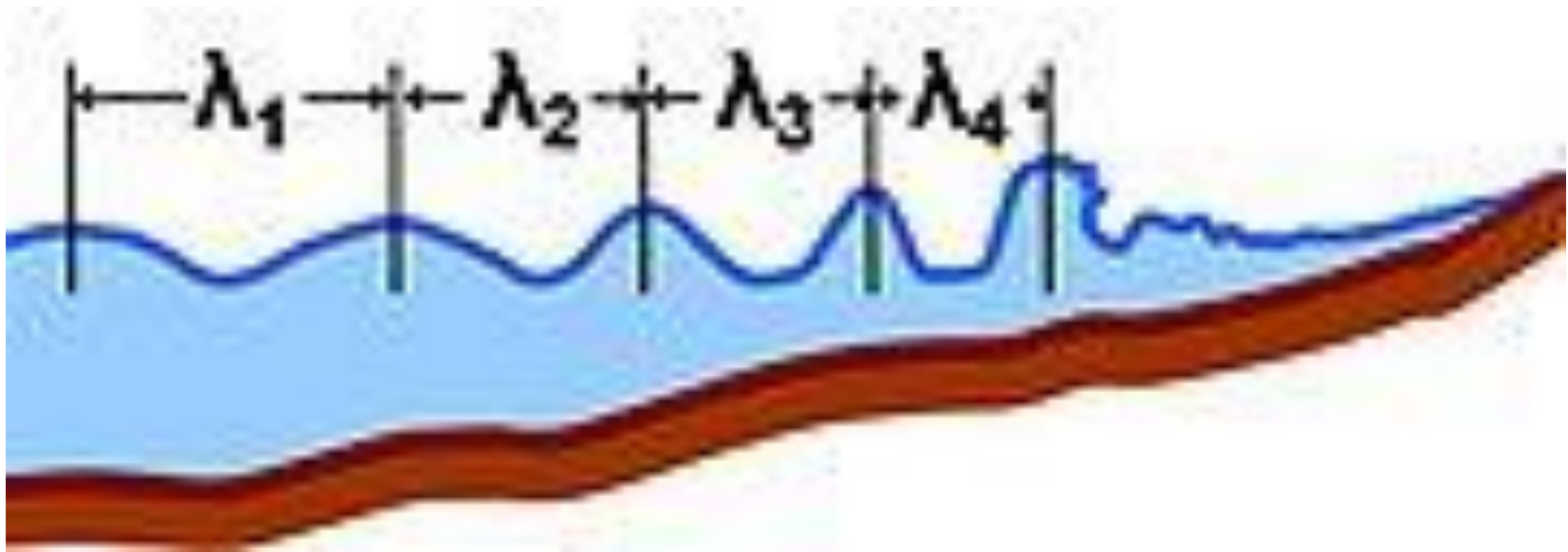
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wave phase :  $t / T = 0.000$

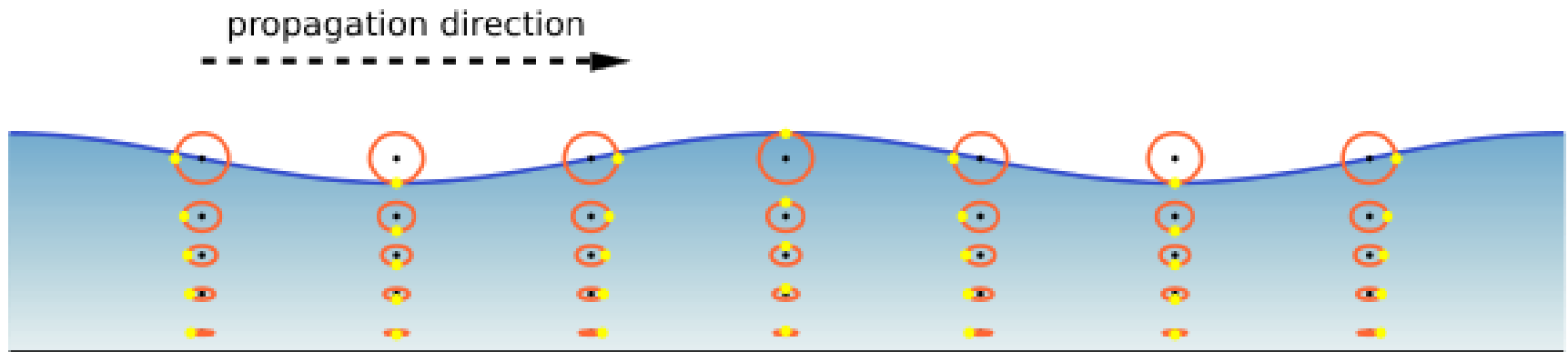


# A breaking water wave

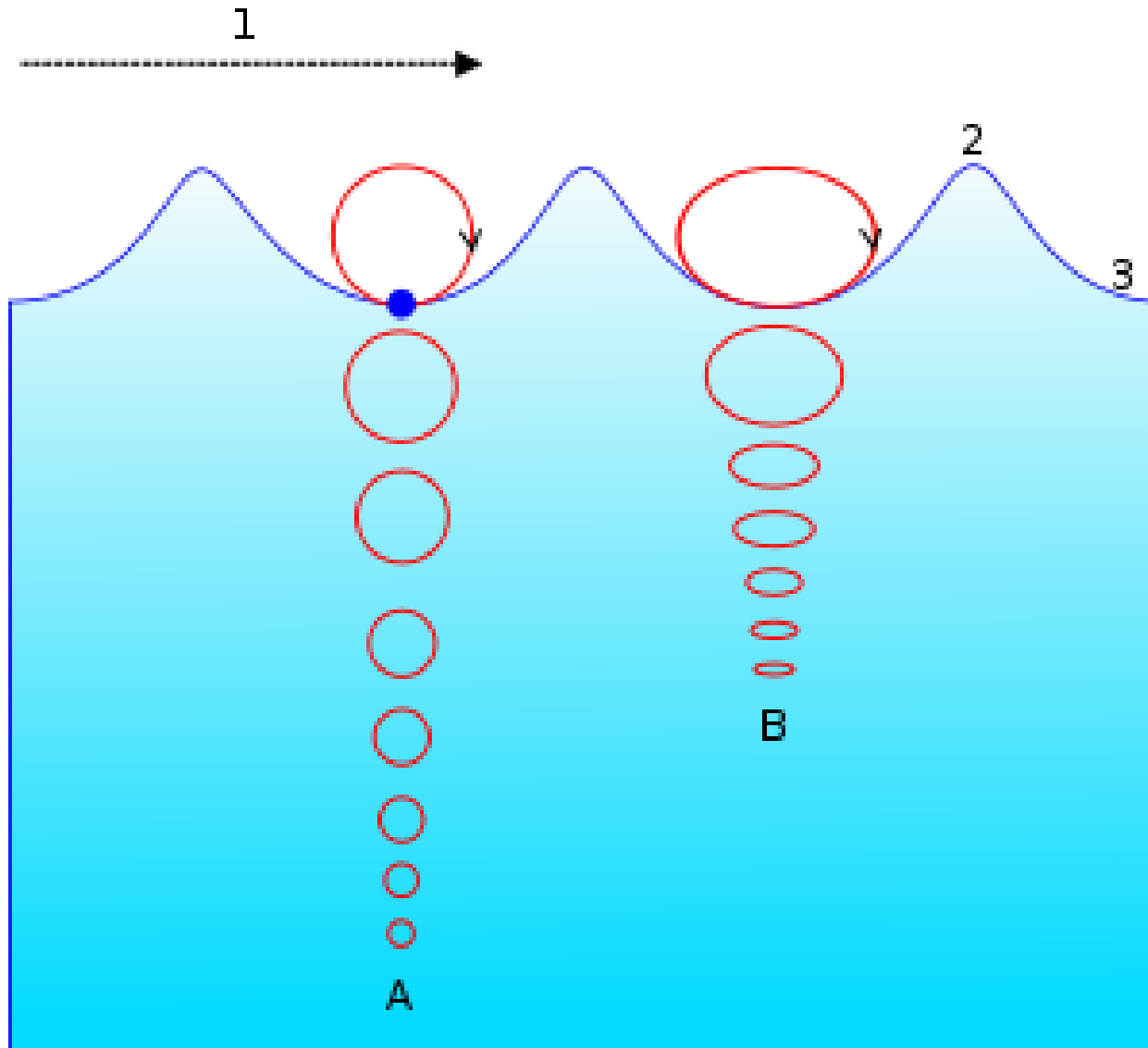
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# Gentle water wave particles execute near circular motion



# In shallow larger amplitude waves particle motion becomes elliptical



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

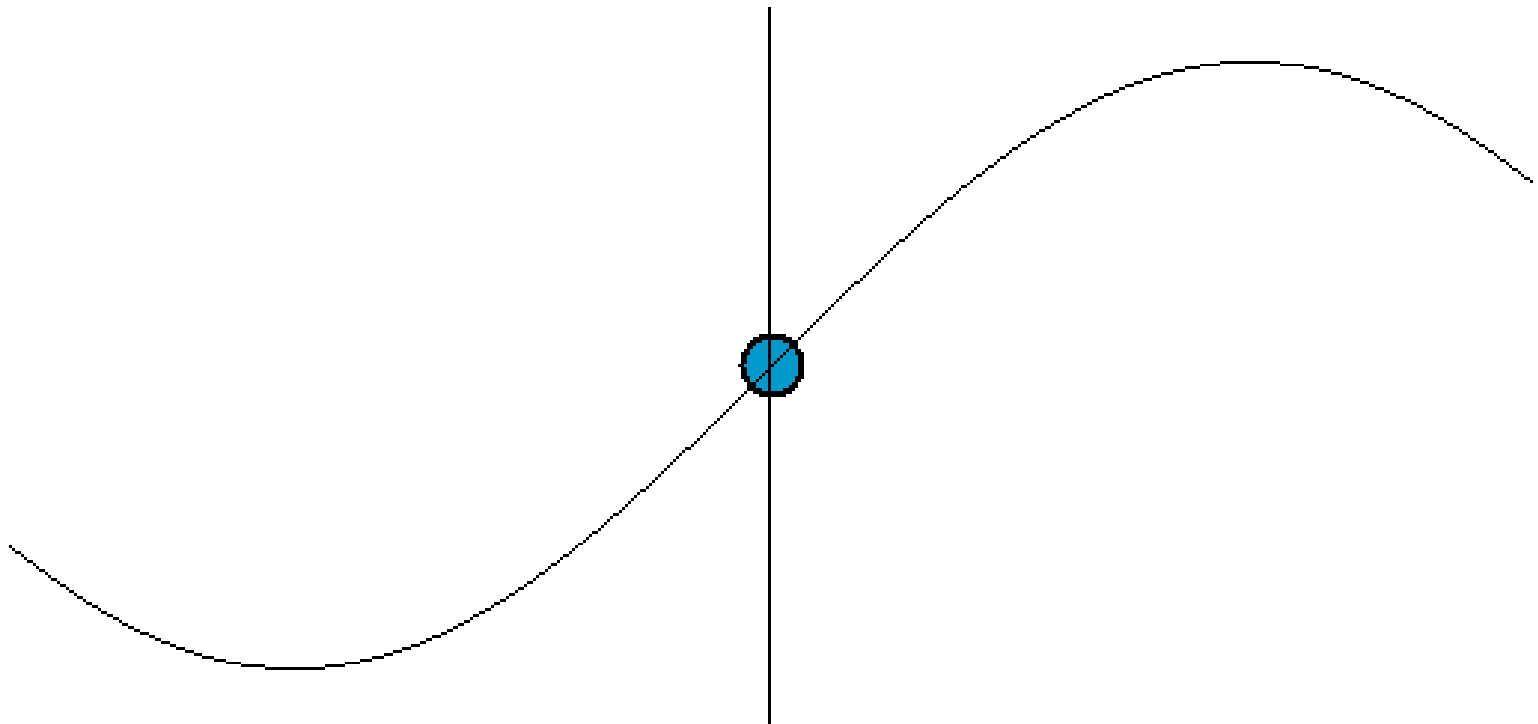
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$\omega$ =angular freq (radians/sec)

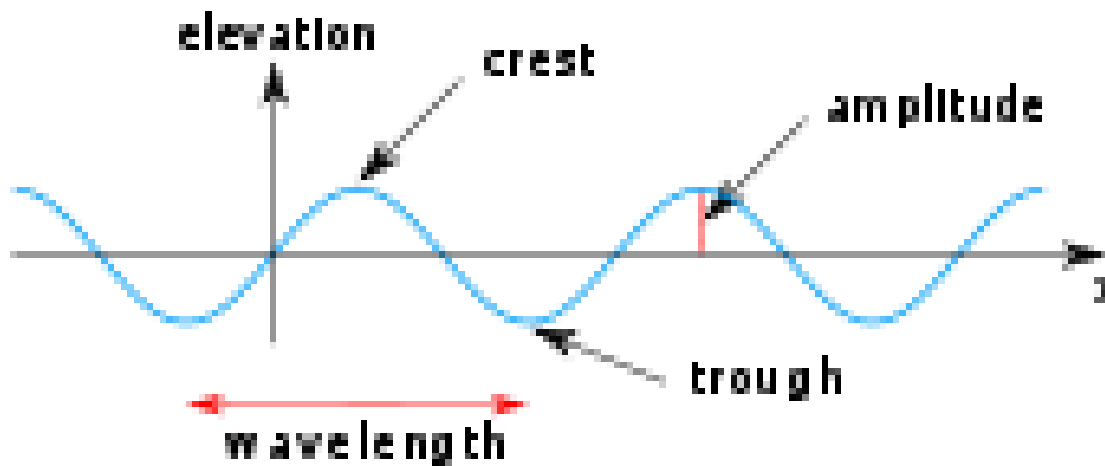
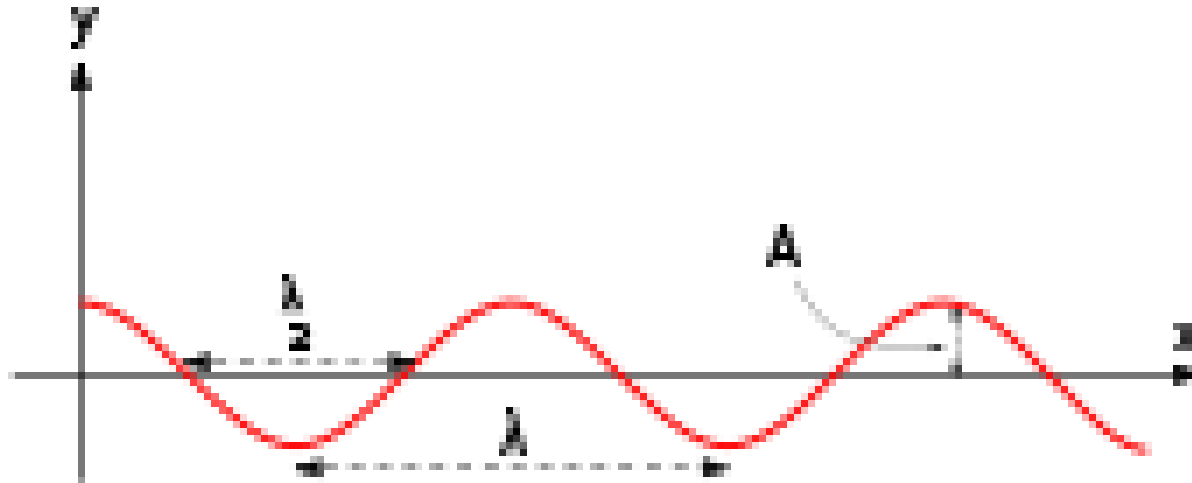
$t$ =time

$\phi$ =Phase shift (angular – radians)

$A$ =Amplitude



# Wave notation



**Frequency=f, Period=T, Angular freq= $\omega$**

**Wavelength= $\lambda$  Wave number=k**

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

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

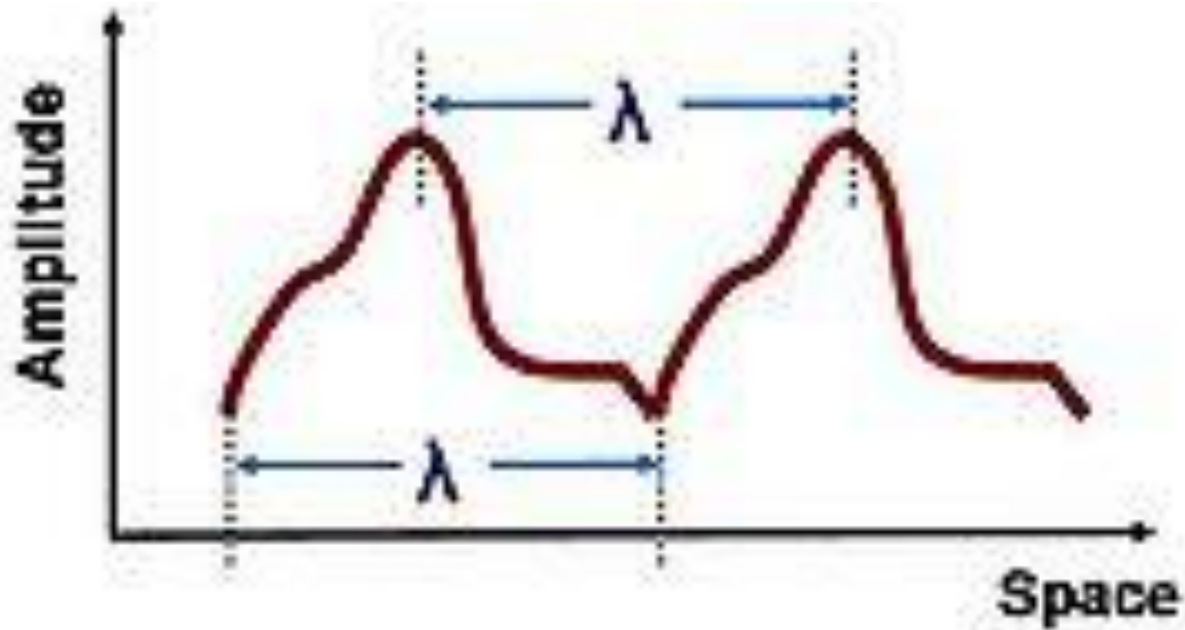
For a purely sinusoidal wave the wavelength and frequency are inversely related

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

$$\omega = v * k$$

**dispersion relation**

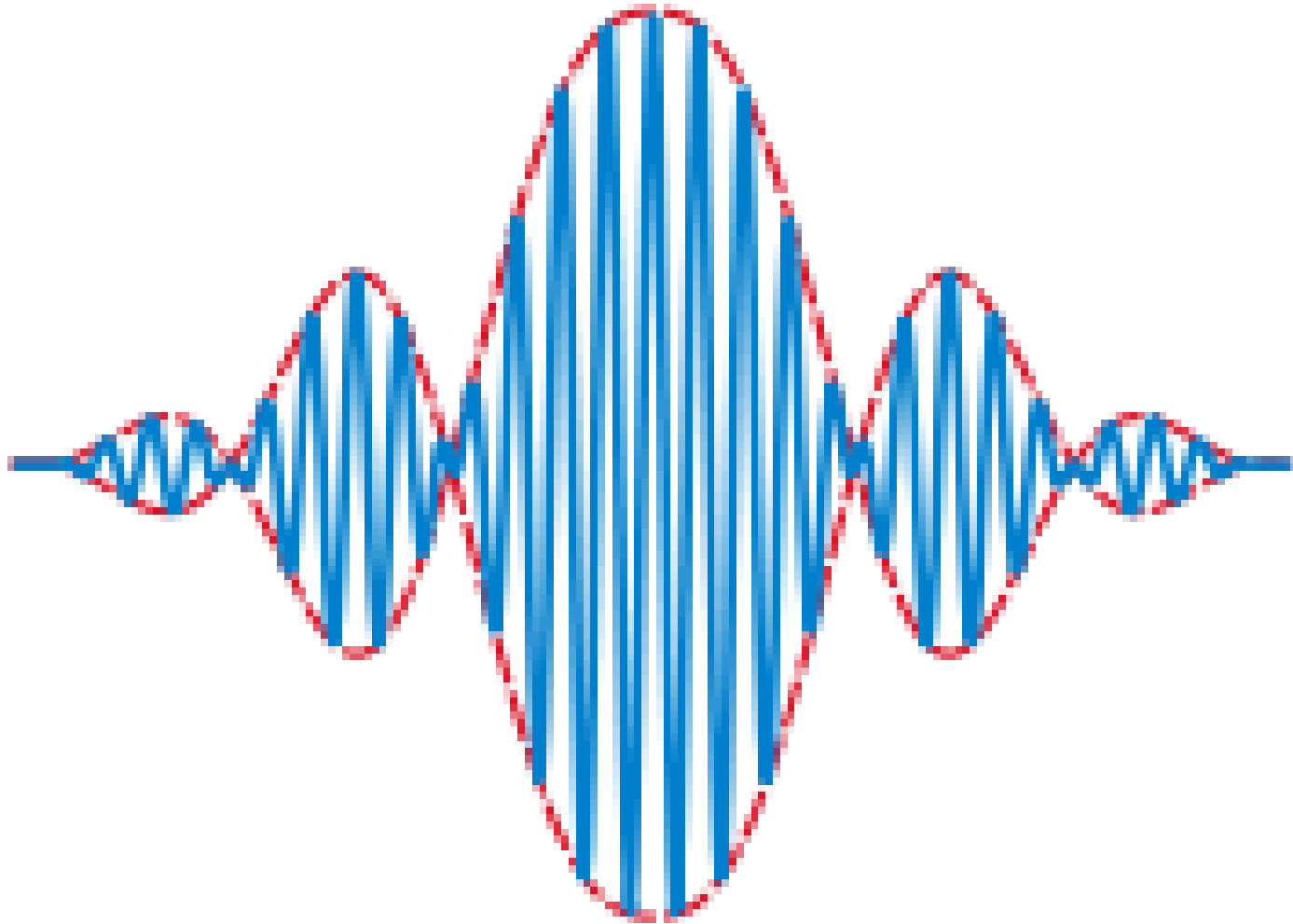
**Not all waves are sinusoidal – normally they are periodic  
hence have a specific wavelength**



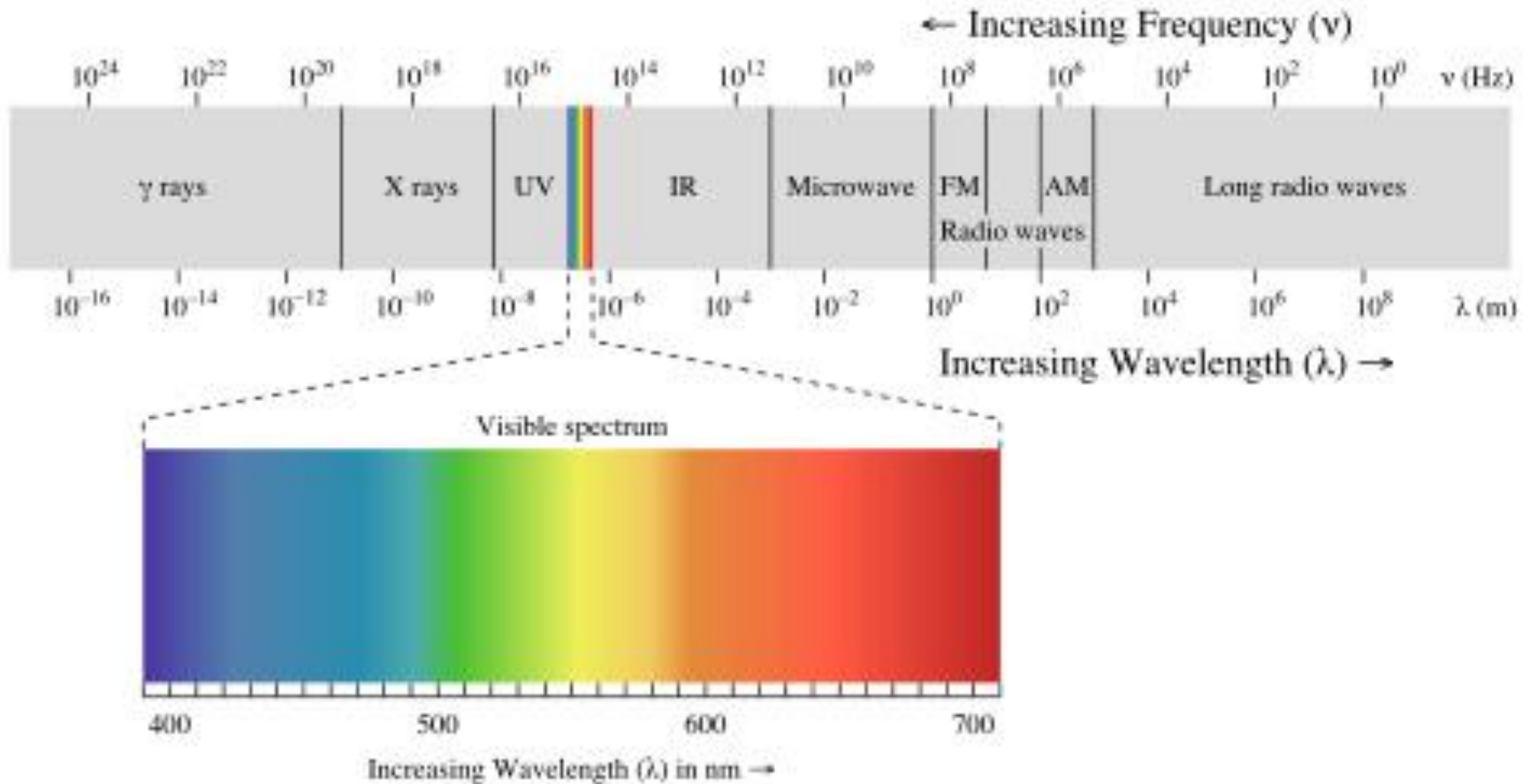
# Wave can add and we get packets of waves

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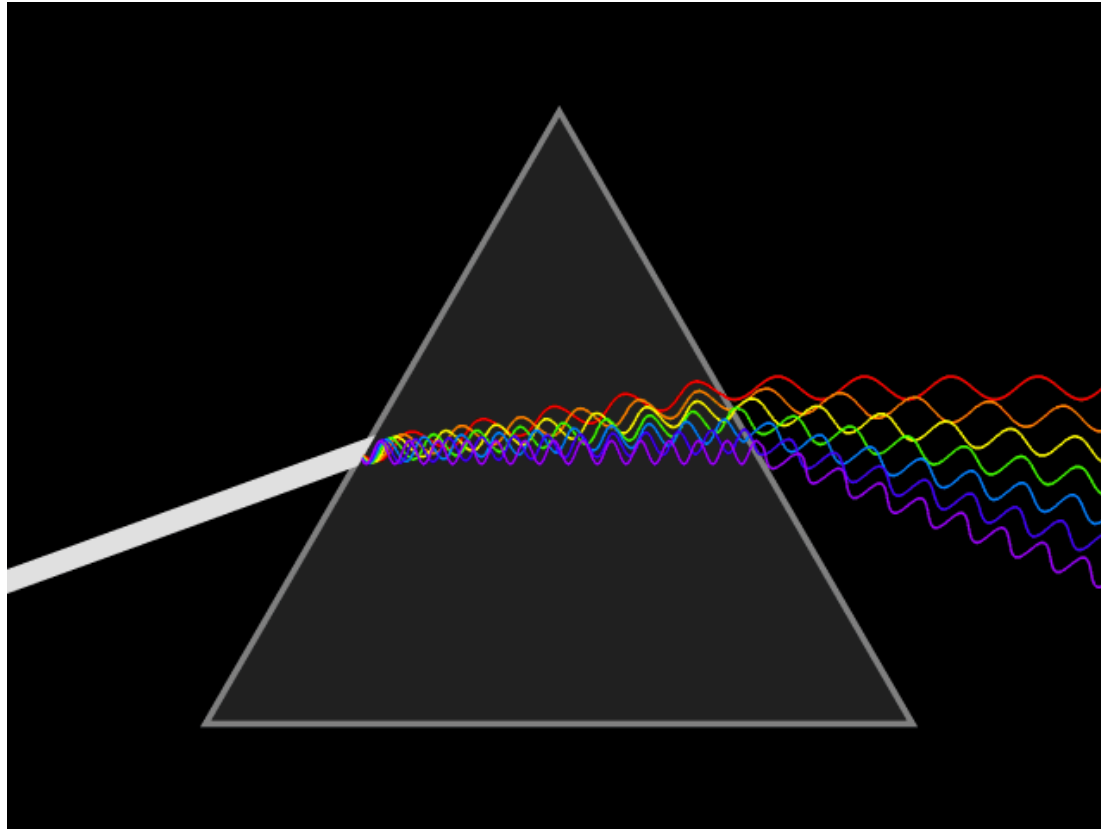
## We call this a Wave Packet



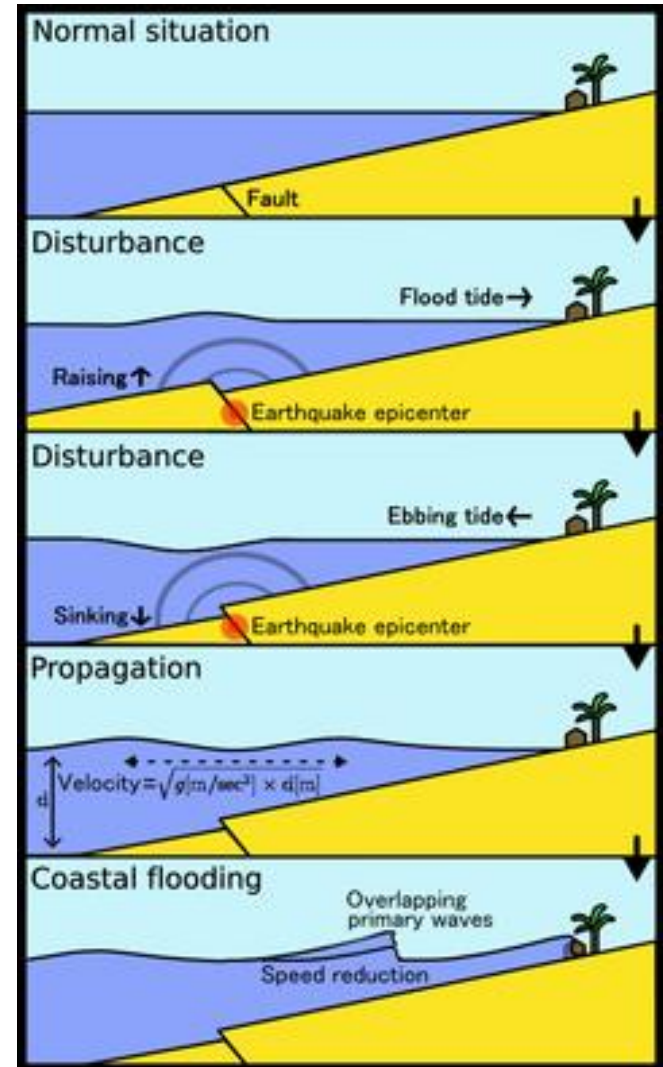
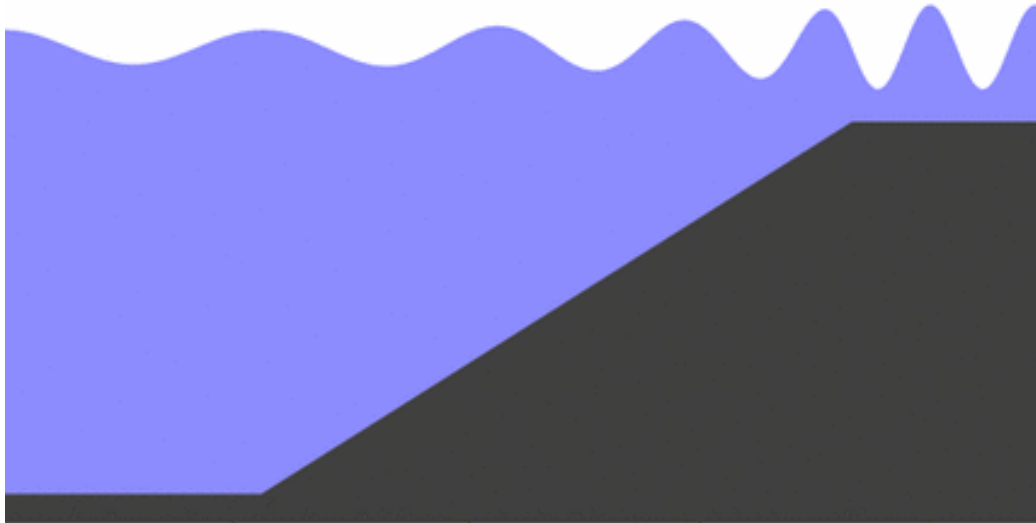
# Other waves – Electromagnetic Waves



**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

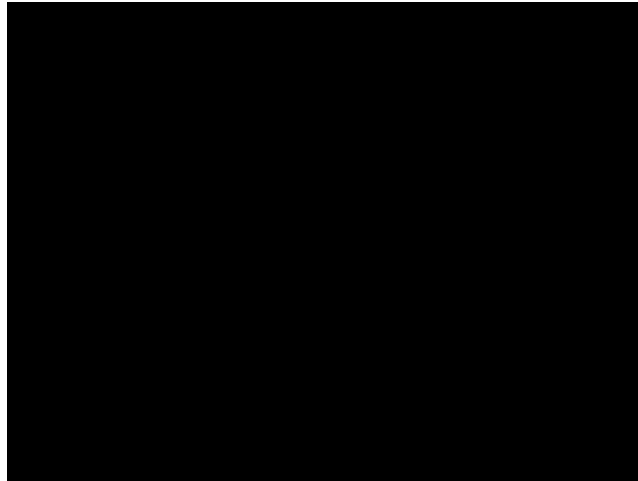
Large Tsunamis can have speeds exceeding 500 MPH!!

An asteroid hit in the ocean could be supersonic



# Samoan Tsunami Sept 2009

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# Group speed vs phase speed

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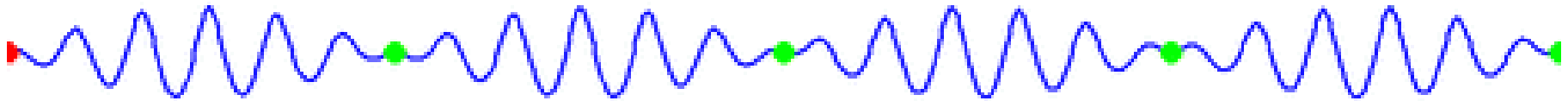
Red is phase Green is group

Phase speed tracks a given phase (any)

Group speed track the group packet speed

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

$$v_p \geq v_g$$



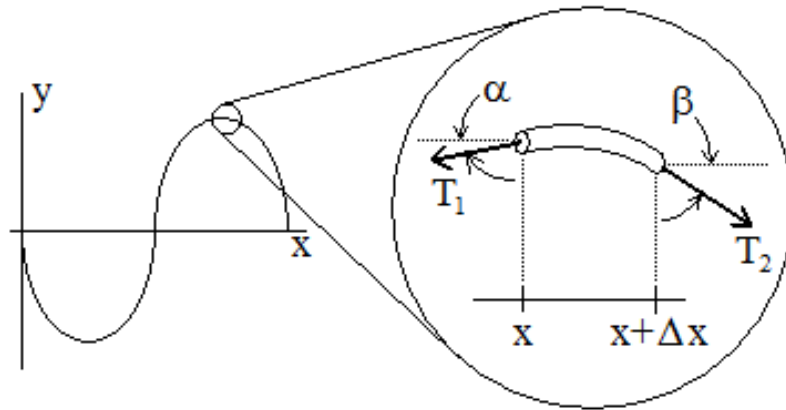
# Standing waves have fixed boundary conditions

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## A piano and a guitar are examples



# String (wire) under tension (T) [ $\mu$ =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

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2<sup>nd</sup> order linear diff eq – simple sin, cos solution

$y = A \cdot \sin(\text{or cos})(x \pm vt)$

Use Fourier transform to get any solution

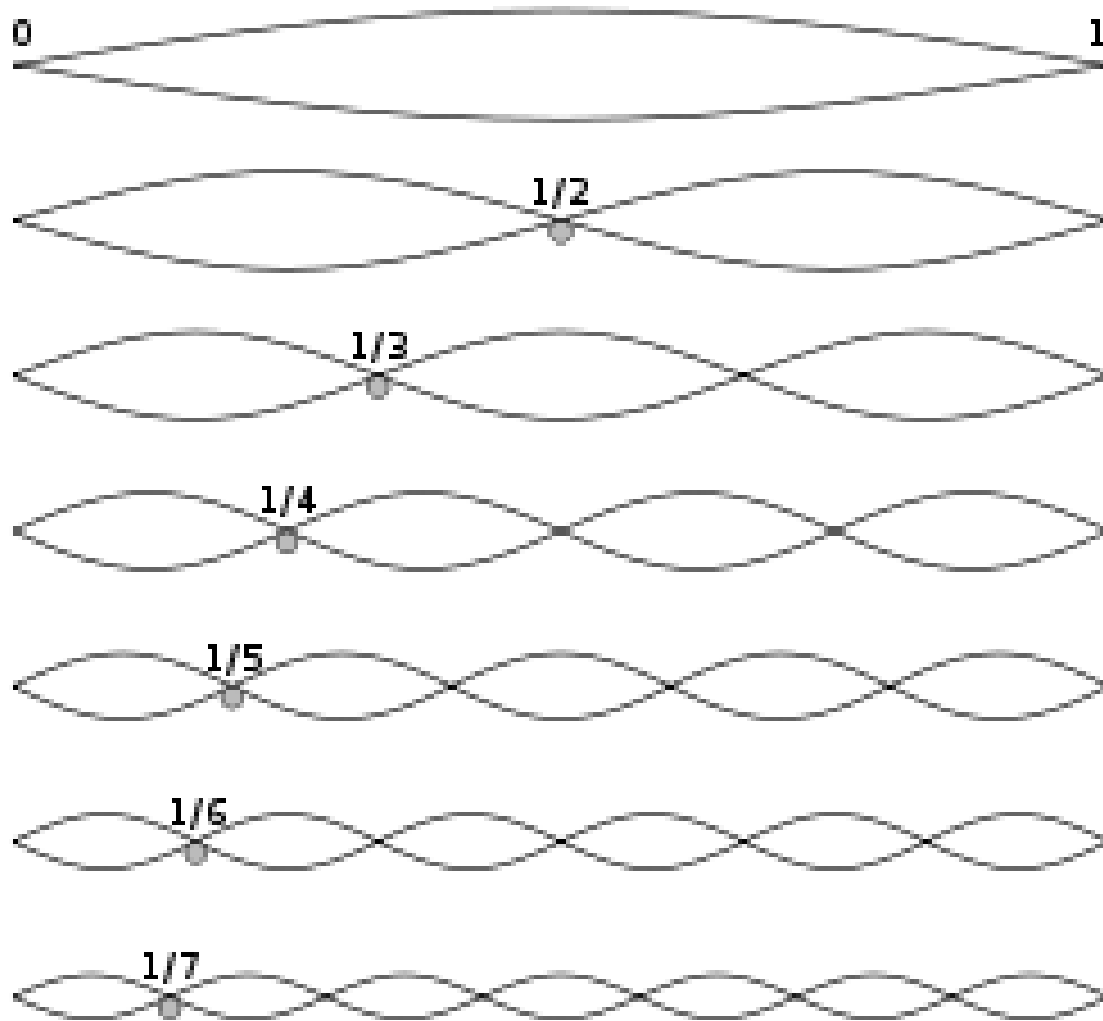
$$\frac{\partial^2 y}{\partial x^2} = \frac{\mu}{T} \frac{\partial^2 y}{\partial t^2}$$

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

# Standing Waves on a string

## Fundamental and 6 harmonics

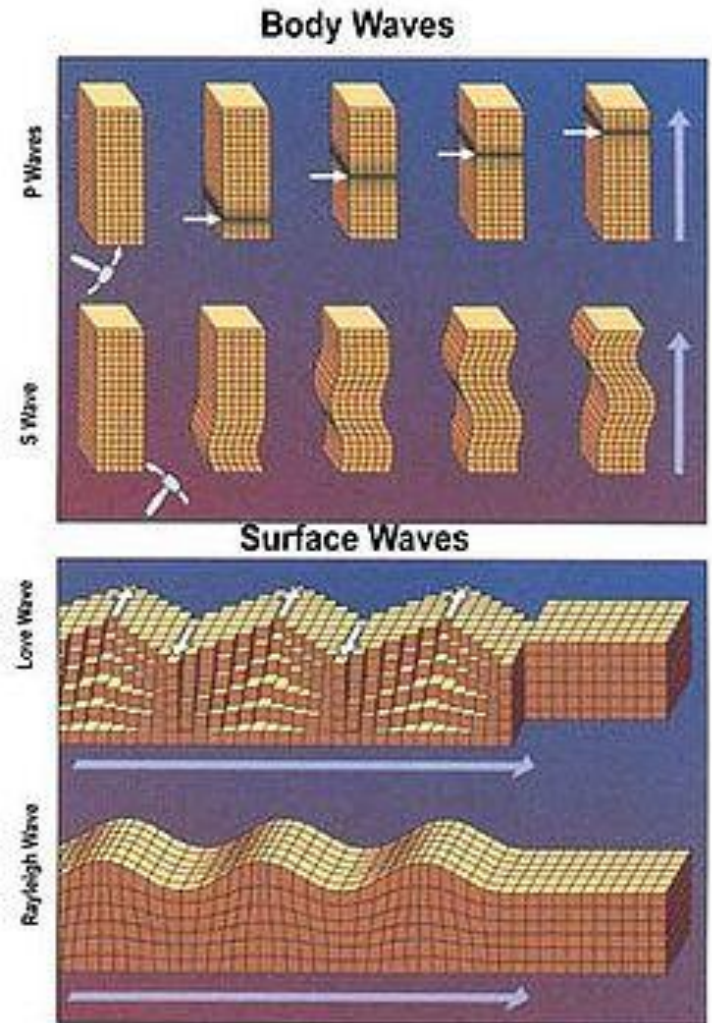
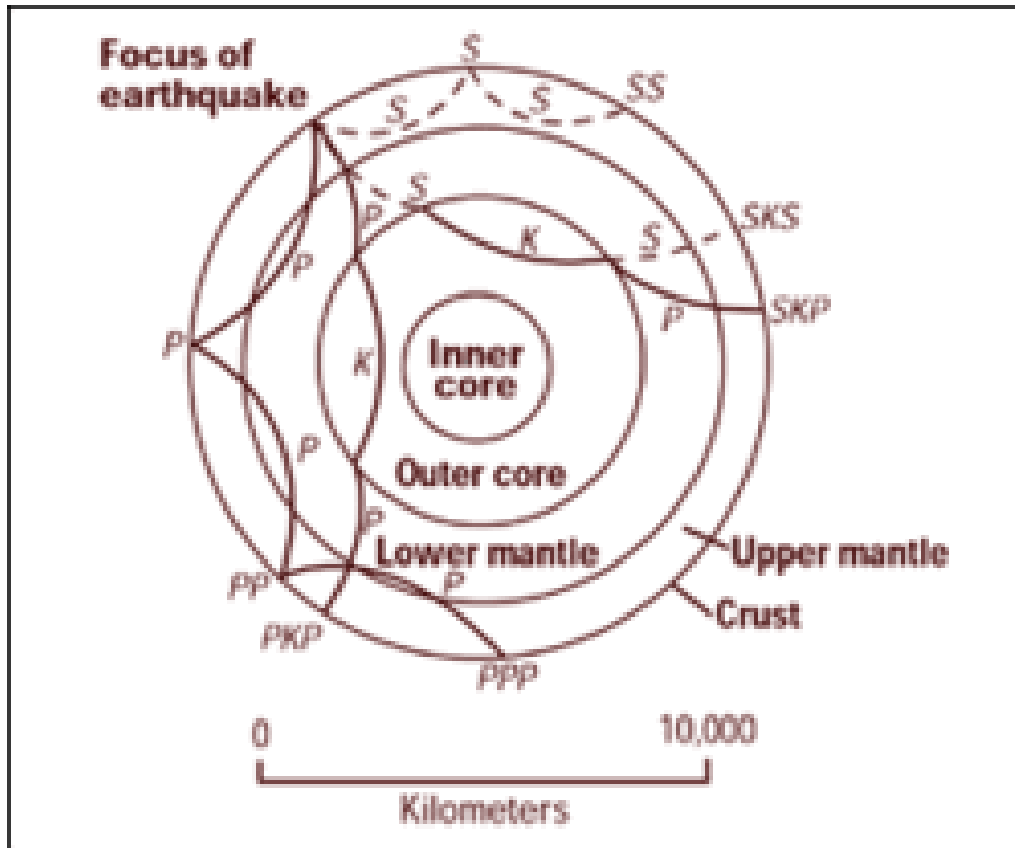
Such studies date back to Ancient Chinese ~3000BC



# Body and Surface waves in the earth

S – “Secondary” transverse shear wave

P – “Primary” longitudinal compressional wave



## S and P waves – body waves

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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

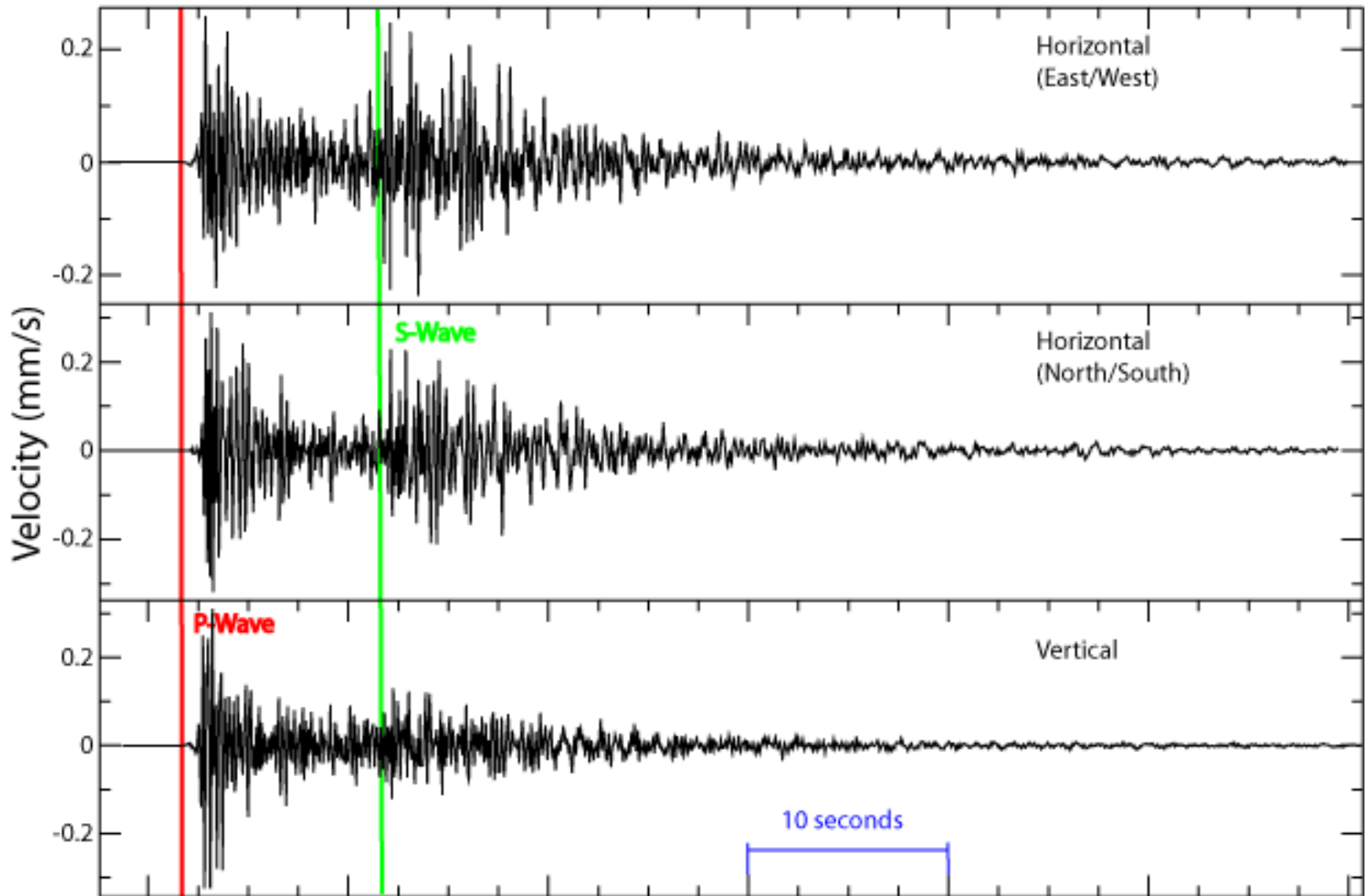
P waves travel faster hence arrive first

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

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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

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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  $\sim 3/2$  power of displacement

Difference of 1 =  $(10)^{3/2} \sim 32$  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

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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 Francisco 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

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$$M_n = \frac{2}{3} \log_{10} \frac{m_{\text{TNT}}}{\text{Mt}} + 6$$

$m_{\text{TNT}}$  is the yield in MegaTons (MT) – TNT equivalent

1 Ton TNT ([trinitrotoluene](#)) ~  $10^9$  calories ~  $4 \times 10^9$  Joules

Largest US underground test was ~ 5MT

Codenamed Cannikin on Nov 6, 1971 in the Aleutian Islands

For 5 MT this would yield about  $M \sim 6.5$

Note – 1 KiloTon (1 KT)  $M \sim 4$

0.5-1% of yield goes into earthquake energy

1 Kg matter annihilation ~ 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

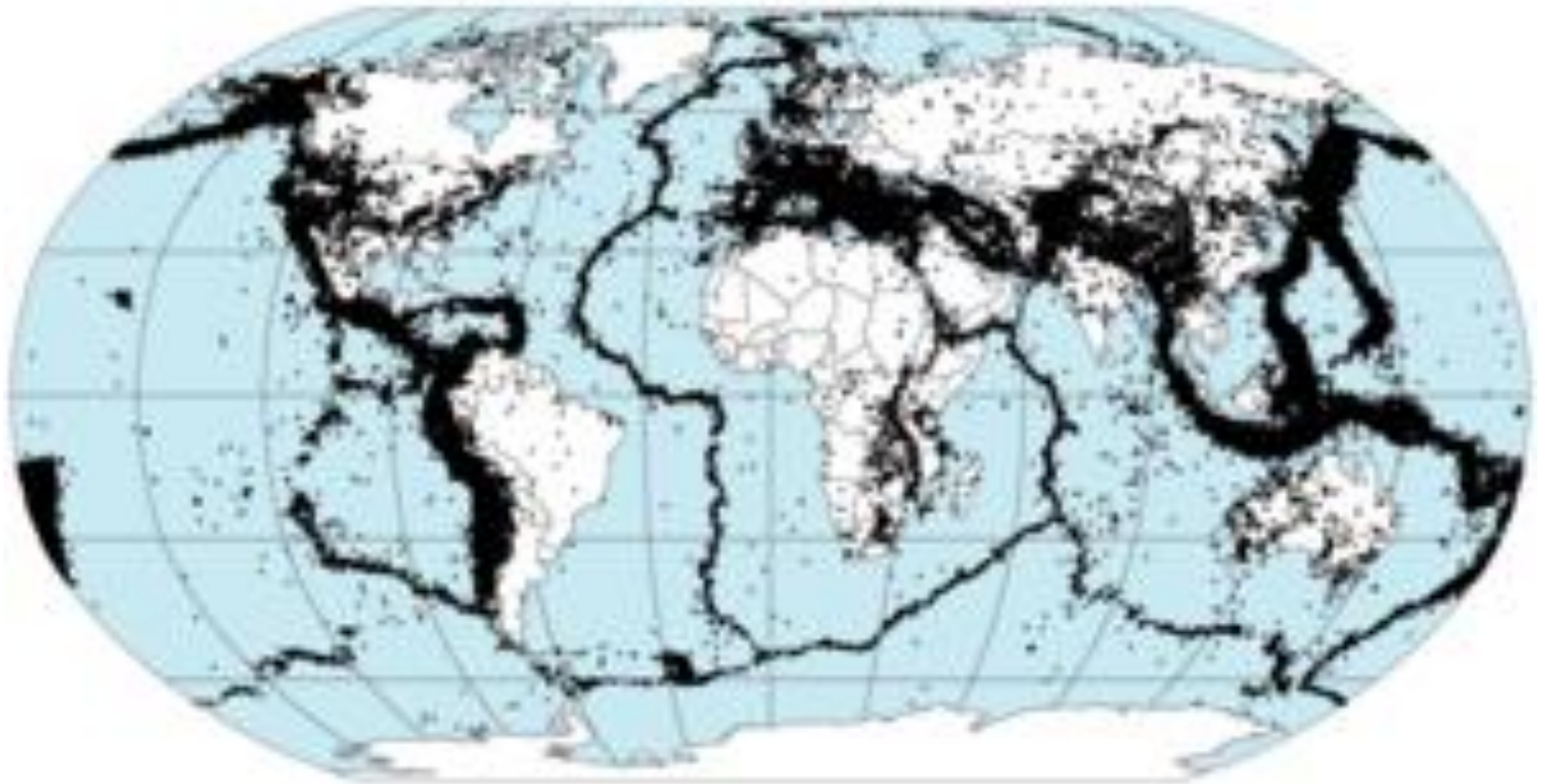
- Northridge Earthquake 1971 ->
- Loma Prieta Oct 1989 others



# Earthquakes are not uniformly distributed

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Preliminary Determination of Epicenters  
358,214 Events, 1963 - 1998



# **Body waves can be used for exploration – oil, etc**

**Example below is explosive driven wave to look for land mines**

