Waves and vibrations

Categorising waves:

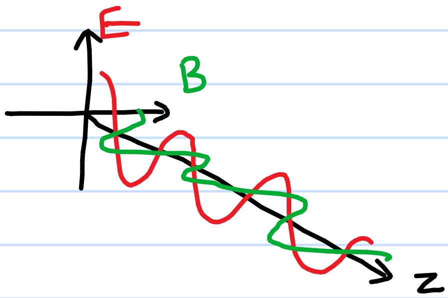
Mechanical Oscillating matter	or	Electromagnetic Oscillating electric & magnetic fields
Longitudinal displacement is parallel to energy propogation	or	Transverse displacement is perpendicular to energy propogation
progressive non-zero net energy propagation	or	stationary zero net energy propagation.

Longitudinal wave vocabulary: compression - high density
rarefaction - low density

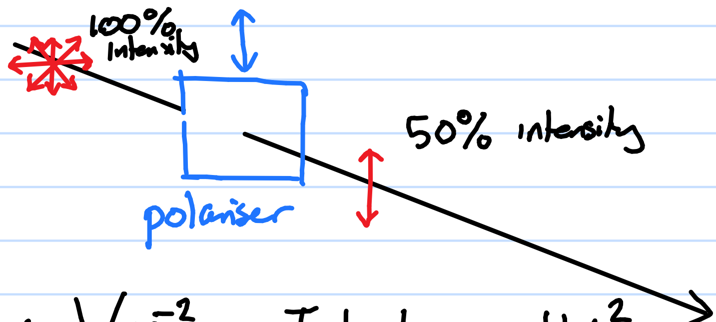
Transverse wave vocabulary: peak / crest - highest positive displacement
trough - highest negative displacement

Polarisation

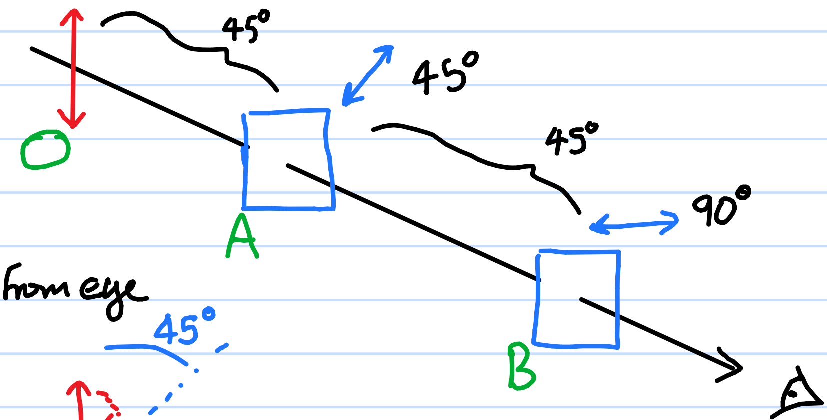
Only transverse waves can be polarised



Polarisers polarise unpolarised light



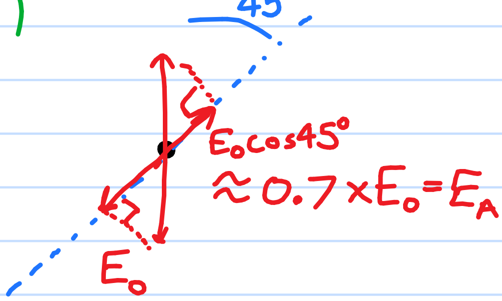
Intensity measured in Wm^{-2} Intensity $\propto$ amplitude^2



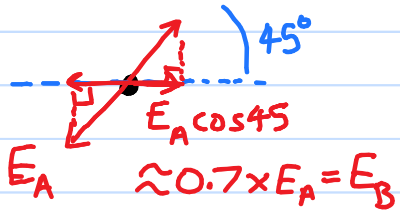
$0.7 \times 0.7 \times E_0$
$\approx 0.5 E_0$

Looking from eye

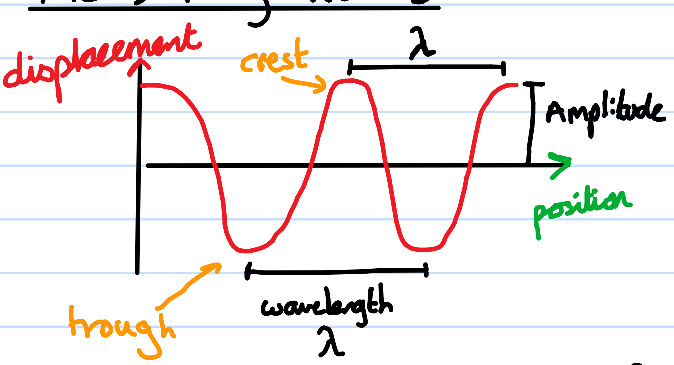
A)

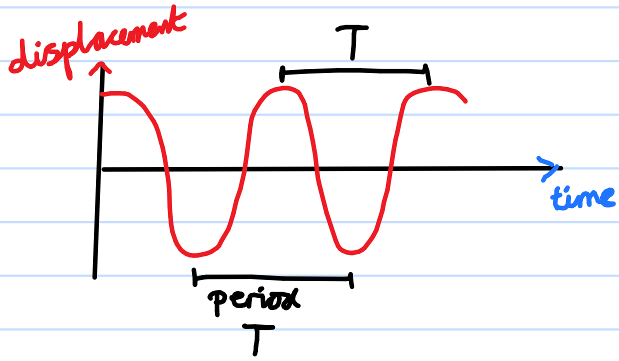


B)



Measuring Waves





$$c = \frac{\lambda}{T}$$

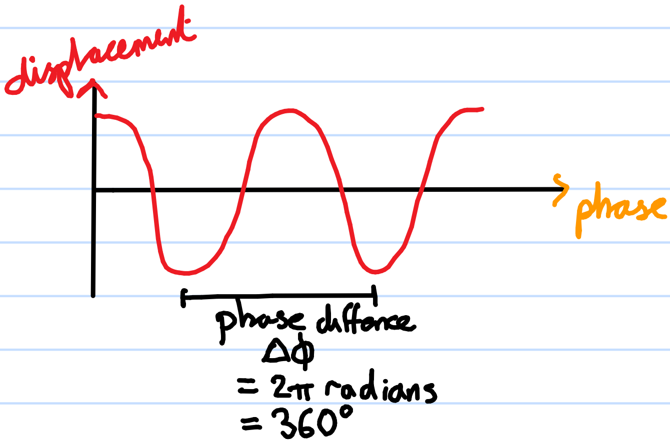
wavespeed

$$f = \frac{1}{T}$$

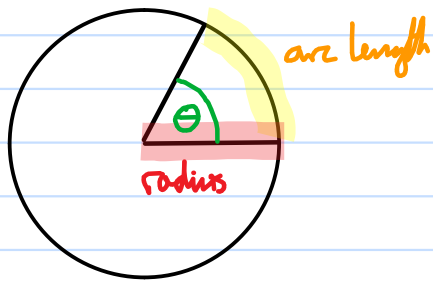
frequency

(if f in hertz, number of waves passing a position per second.)

$$\boxed{c = f\lambda}$$



Define radians



Circumference = diameter × π

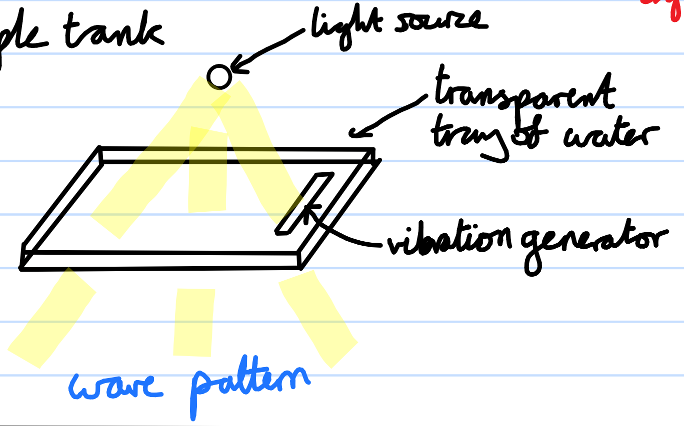
$\theta = 1$ radian if arclength = radius

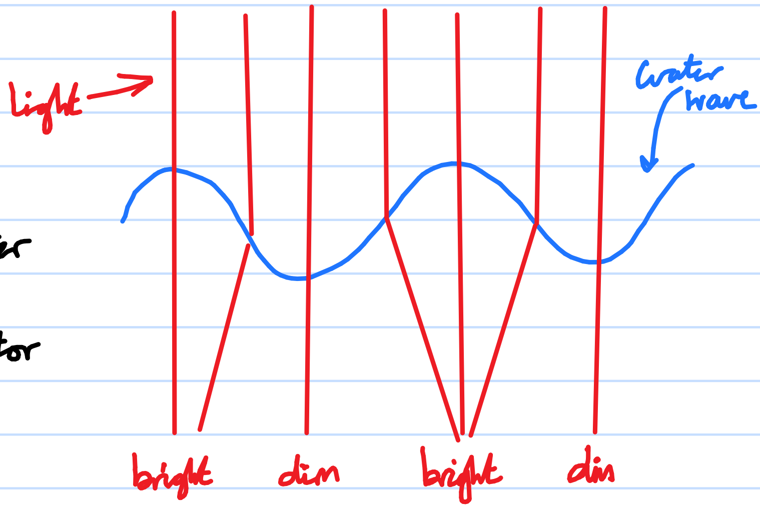
$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} = \frac{\Delta t}{T} = \text{fraction of cycle}$$

$$\boxed{\Delta\phi = 2\pi\frac{\Delta x}{\lambda} = 2\pi\frac{\Delta t}{T}}$$

Wave properties 1

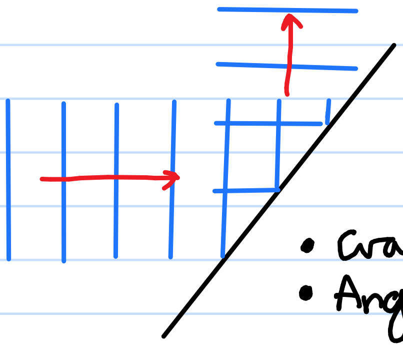
ripple tank





Waves can interfere / superposition

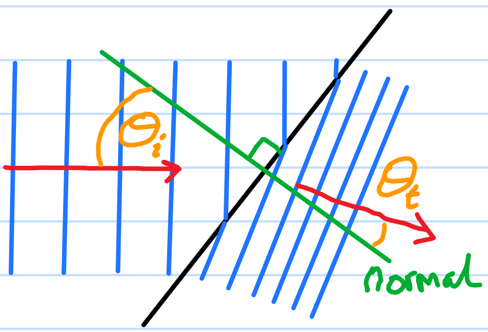
Reflection:



= direction of wave propagation
= wavefronts (same phase)

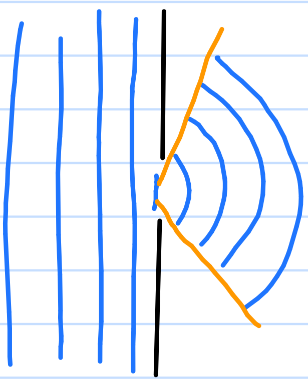
- wavefronts always perpendicular to wave propagation
- Angle of incidence = angle of reflection

Refraction:

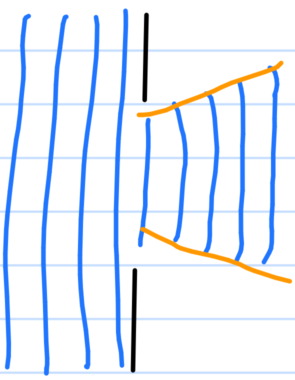


- $c = f\lambda$, c is reduced in this example
- $\therefore \lambda$ is also reduced because f does not change
- if wave slows, $\theta_t < \theta_i$
  θ_t = angle of refraction
  θ_i = angle of incidence

Diffraction:



Small gap : big spread

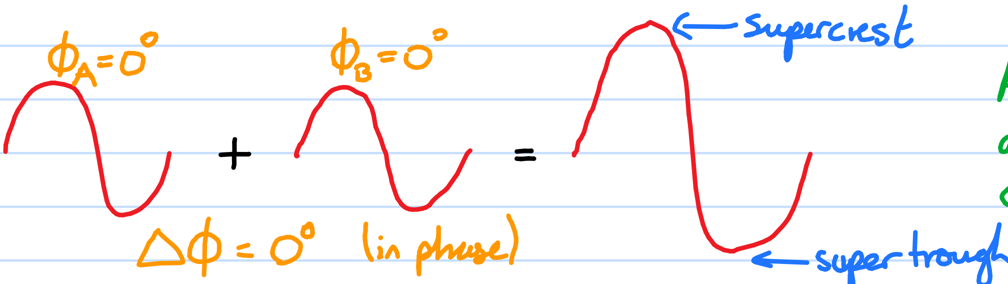


big gap : small spread

Wave properties 2

Superposition: adding together the effect of two or more waves

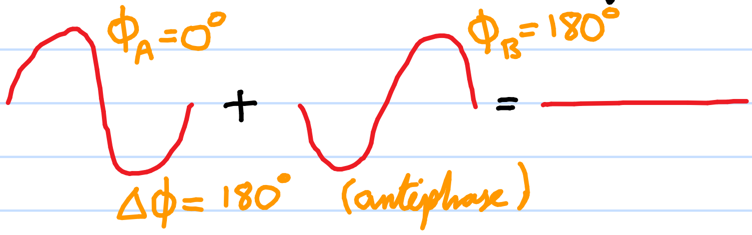
Reinforcement / constructive interference:



At each instant in time we add together the displacements of each wave

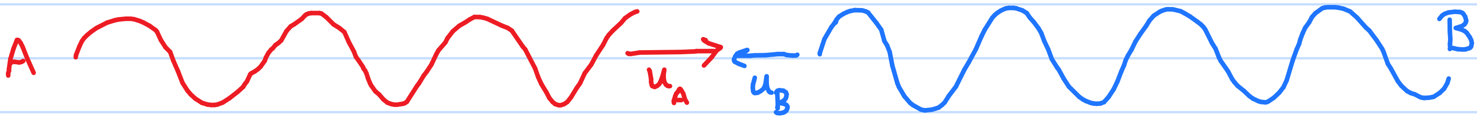
If displacements are in the same direction, their addition increases the magnitude of the resultant displacement

Cancellation / destructive interference:



the displacements are always in opposite directions, so their addition decreases the magnitude of the resultant displacement

Two wave superpositioning:

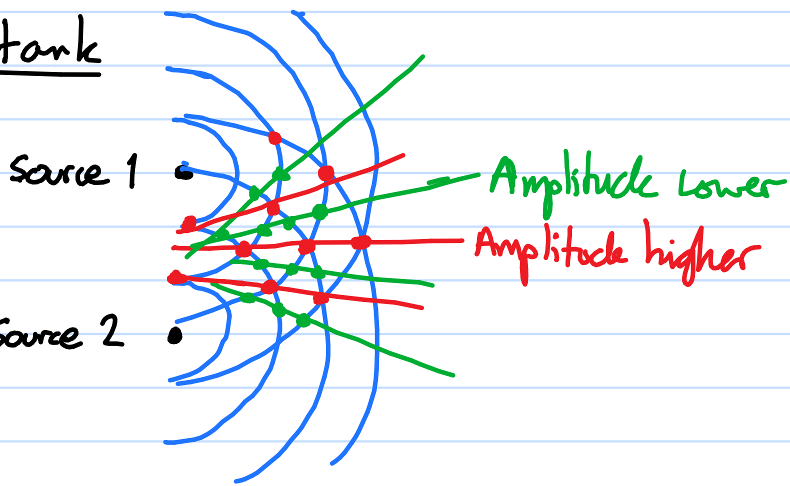


- At one instant in time all crests from A align with crests from B
- At a different instant in time, all crests from A align with troughs from B

This forms a stationary wave: Nodes – crests of A align with troughs of B

Antinodes – crests of A align with crests of B

Ripple tank



Stationary and progressive waves

Stationary waves on strings:

N = node (amplitude of stat. wave = 0)

A = Antinode (amplitude = maximum)

Wavelength of progressive waves that are added to form a stationary are 2× distance between adjacent nodes

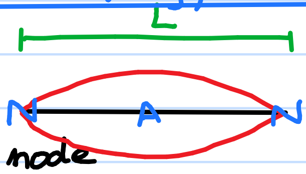
Harmonics:

Waves on string, two fixed boundaries

L = Length of string

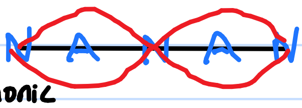
$c = f\lambda$ and c (progressive wave speed) does not depend on f or λ.

$n=1$
Fundamental mode



$f = f_1$
$\lambda = \lambda_1 = 2L$

$n=2$
Second harmonic

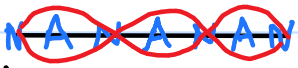


$f = f_2 = 2f_1$
$\lambda = \lambda_2 = \frac{1}{2}\lambda_1 = \frac{2}{2}L$

$f_n = nf_1 \qquad \lambda_n = \frac{\lambda_1}{n} = \frac{2L}{n}$

$c = f_n\lambda_n = \cancel{n}_1 f_1 \times \frac{2L}{\cancel{n}}$

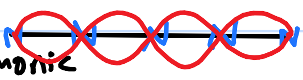
$n=3$
third harmonic



$f = f_3 = 3f_1$
$\lambda = \lambda_3 = \frac{1}{3}\lambda_1 = \frac{2}{3}L$

$$\boxed{f_n = \frac{n}{2L} \times c}$$

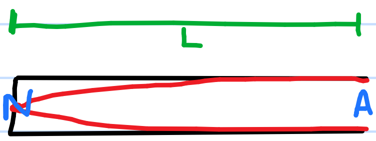
$n=4$
Fourth harmonic



$f = f_4 = 4f_1$
$\lambda = \lambda_4 = \frac{1}{4}\lambda_1 = \frac{2}{4}L$

Waves in a pipe, one fixed boundary, one open boundary

$n=1$

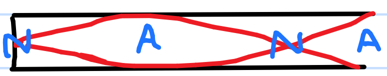


$f = f_1$
$\lambda = \lambda_1 = 4L$

$\lambda_n = \frac{4L}{2n-1}$

$c = f_n \frac{4L}{(2n-1)}$

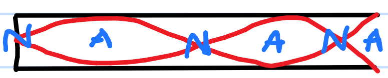
$n=2$



$f = f_2 = 3f_1$
$\lambda = \lambda_2 = \frac{1}{3}\lambda_1 = \frac{4}{3}L$

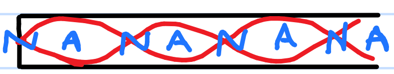
$$\boxed{f_n = \frac{(2n-1)}{4} \cdot \frac{c}{L}}$$

$n=3$



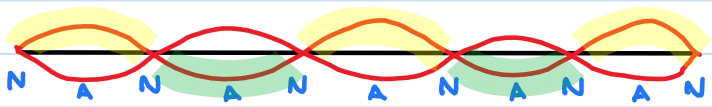
$f = f_3 = 5f_1$
$\lambda = \lambda_3 = \frac{1}{5}\lambda_1 = \frac{4}{5}L$

$n=4$



$f = f_4 = 7f_1$
$\lambda = \lambda_4 = \frac{1}{7}\lambda_1 = \frac{4}{7}L$

More about stationary waves on strings



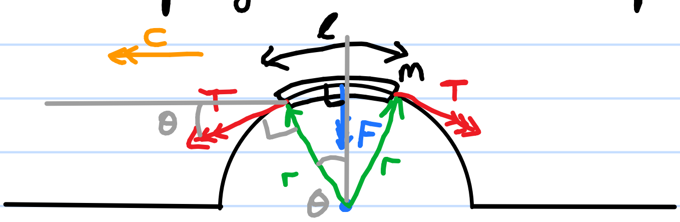
If there is an odd number of nodes between two points, $\Delta\phi = \pi$ radians $= 180°$

If there is an even number of nodes between two points, $\Delta\phi = 0$

String bound at both ends:

$f_n = \frac{n}{2L} \times c$ derive c (speed of wave) in terms of T (tension) and μ (linear density / mass per unit length of string)

Consider progressive wave as a pulse



$F = ma$

$a = \frac{v^2}{r} = \frac{c^2}{r}$

to be derived in circular motion topic

$F = m\frac{c^2}{r}$

Vertical component of $T = T\sin\theta$
Resultant force $F = 2T\sin\theta$

$2T\sin\theta = m\frac{c^2}{r}$

$\sin\theta = \frac{l}{2r}$

$\cancel{2}T\frac{l}{\cancel{2}\cancel{r}} = m\frac{c^2}{\cancel{r}}$

$Tl = mc^2$

$c = \sqrt{\frac{Tl}{m}}$

$\mu = \frac{m}{l}$ (mass per unit length)

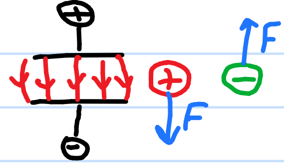
$c = \sqrt{\frac{T}{\mu}}$

$f_n = \frac{n}{2L} \times c$

$\boxed{f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}}$

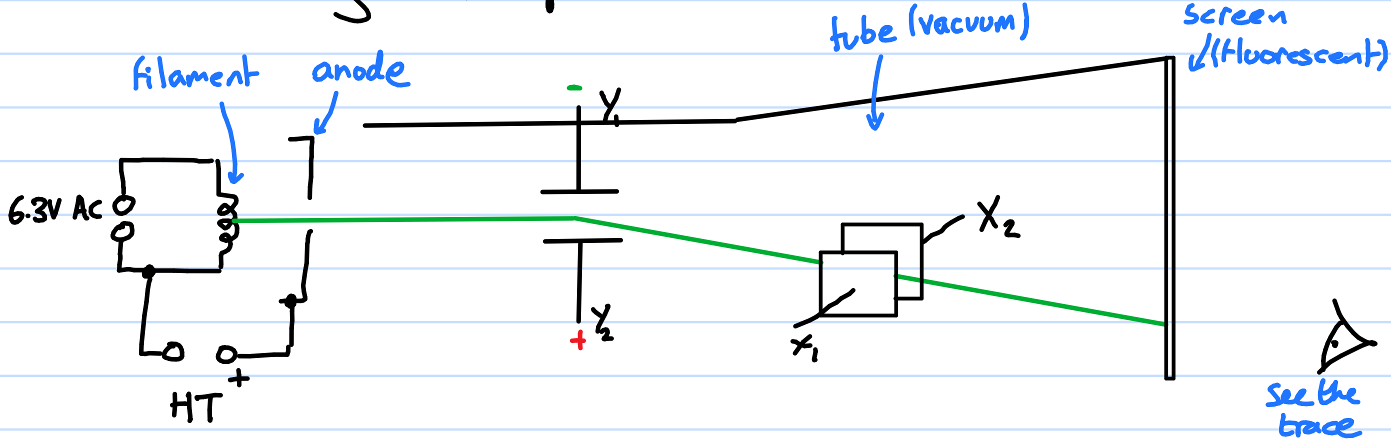
Using an oscilloscope

GCSE:



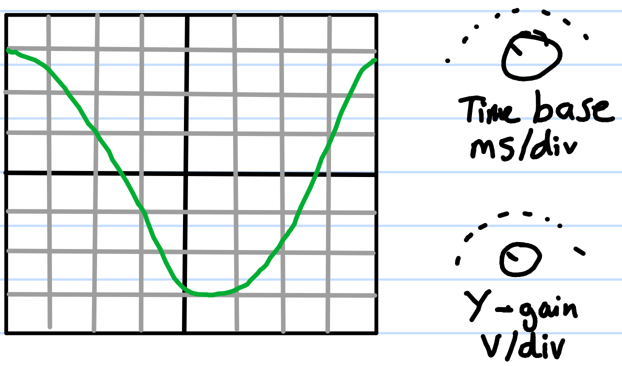
An oscilloscope is a voltmeter.

CRO: Cathode-ray oscilloscope



potential difference between Y_1 & Y_2 influences vertical position of dot on screen
potential difference between X_1 & X_2 influences horizontal "

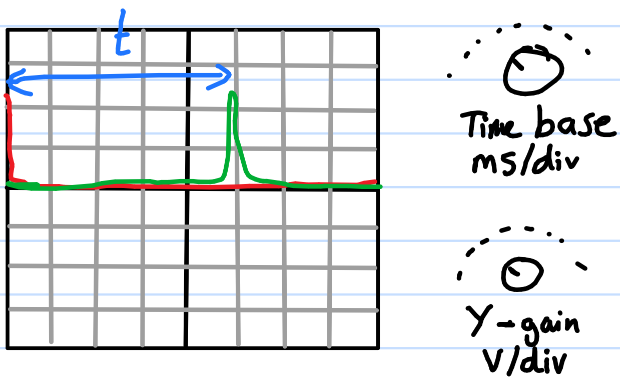
Oscilloscope screen



← Usually adjusted to show at least one period

← usually adjusted to show peak-trough as large as possible

Measuring speed of sound



- Use two channels
- trigger on ch 1, first microphone
- Measure time for sound to reach second microphone on ch 2
- produce series of pulses of sound