Waves – Chapter 10.2 – 10.5

- Transverse vs longitudinal
- Frequency f, wavelength λ, period T, wave speed – $v = \lambda f$
- Harmonic waves: $y(x) = A\sin(kx)$; with $k = 2\pi/\lambda$
- Traveling waves: $y(x, t) = A\sin(kx \pm \omega t)$; with $\omega = 2\pi f$
- For waves on a string $v = \sqrt{\dfrac{T}{m/L}}$
- Total energy is proportional to A^2

Interference

- This is a property of waves
- Waves can pass through each other “like ghosts”
- Whenever two waves overlap in space, they add together – or superpose – in a phenomenon called interference
- For harmonic waves of the same wavelength, when they are in phase they add together leading to constructive interference, and when they are out of phase by 180^o – corresponding to $\lambda/2$ – then they add together leading to destructive interference

Superposition of two equal amplitude harmonic waves

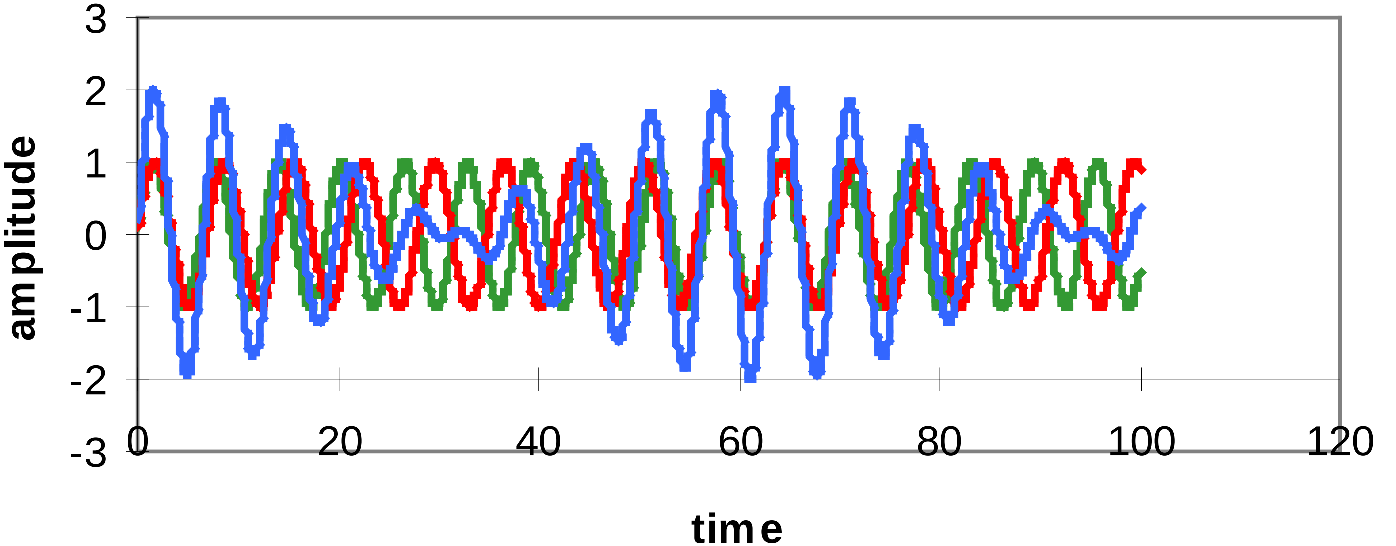
$$y_1 = A\sin(kx - \omega t) \quad and \quad y_2 = A\sin(kx - \omega t + \varphi)$$

$$y = y_1 + y_2 = A\big(\sin(kx - \omega t) + \sin(kx - \omega t + \varphi)\big).$$

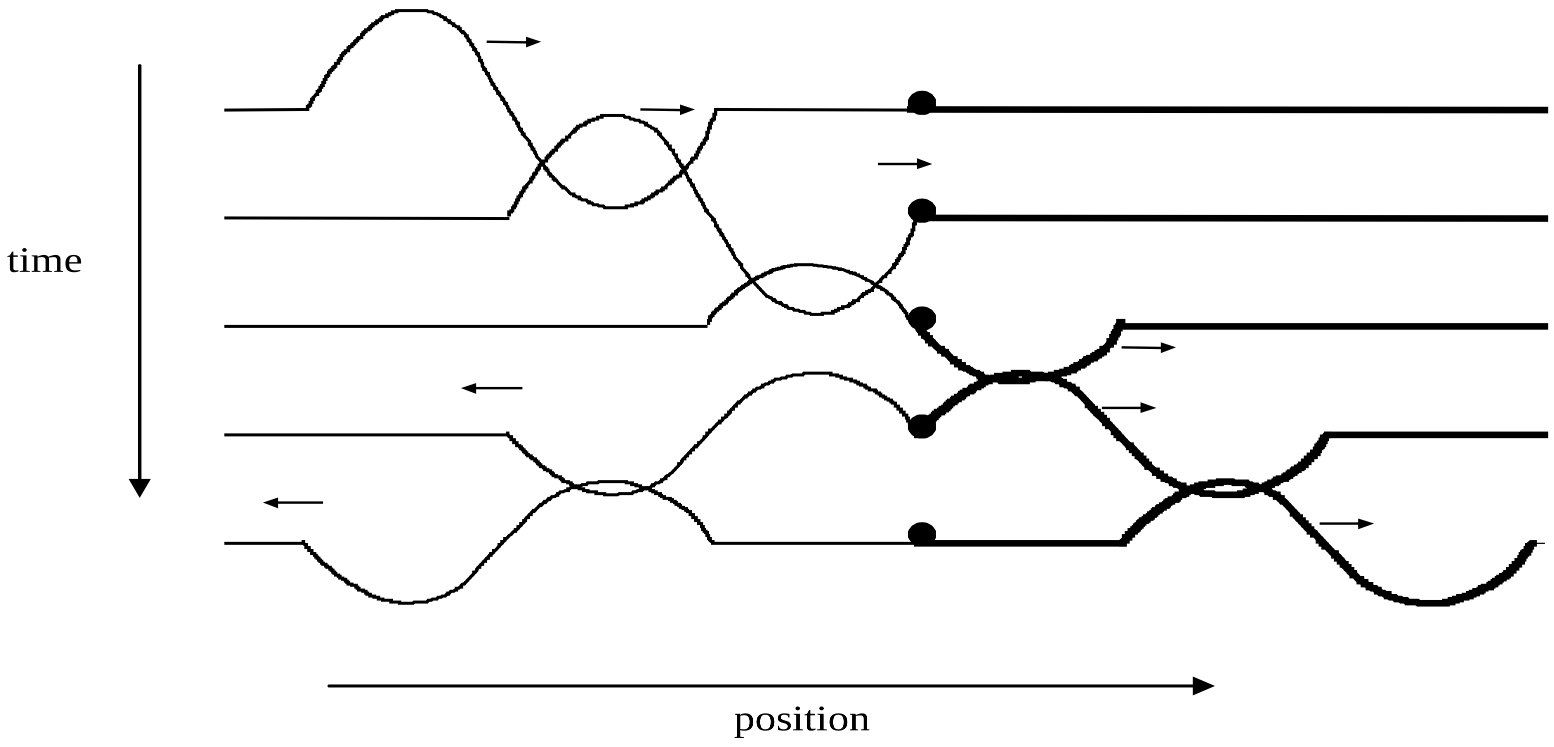
sin α + sin β = 2 sin ½(α+β) cos ½(α-β)

$$y = \left[2A\cos\tfrac{1}{2}\varphi\right]\sin\left(kx - \omega t + \tfrac{1}{2}\varphi\right)$$

Beats



Waves at a Boundary



Standing Waves

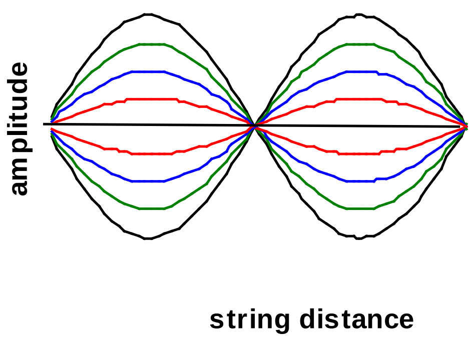
- Superposition of equal amplitude waves traveling in opposite directions

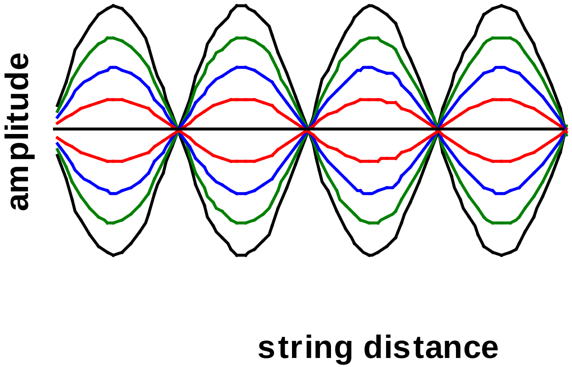
$$y_1 = A\sin(kx + \omega t) \quad and \quad y_2 = A\sin(kx - \omega t)$$

- Using the same trig identity

$$y = y_1 + y_2 = 2A\sin kx \cos \omega t$$

- No longer a traveling wave – but a standing wave





Standing waves on a string

- Only certain frequencies will allow standing waves – we require the wave to reflect and return to the starting point in phase with another oscillation.
- Lowest such resonant frequency (also known as the first harmonic) is the fundamental with $\lambda/2 = L$ so

$$f_1 = v/\lambda = v/2L$$

- Next is the second harmonic with $f_2 = v/L$ since $\lambda = L$ - introduces one node
- In general $\lambda = 2L/n$ and $f_n = nv/2L = nf_1$ - with n-1 nodes

Problem

- Ex. 10.3 A steel guitar string with a 10 gram mass and a total length of 1m has a length of 70 cm between the two fixed points. If the string is tuned to play an E at 330 Hz, find the tension in the string.

Standing Wave Resonance in the sand

Resonance

- Increase in energy input due to a matching of frequencies –
- other examples include NMR, ESR, resonance in springs, in pendula, in sound (we’ll see this one next)