Sound and Acoustics

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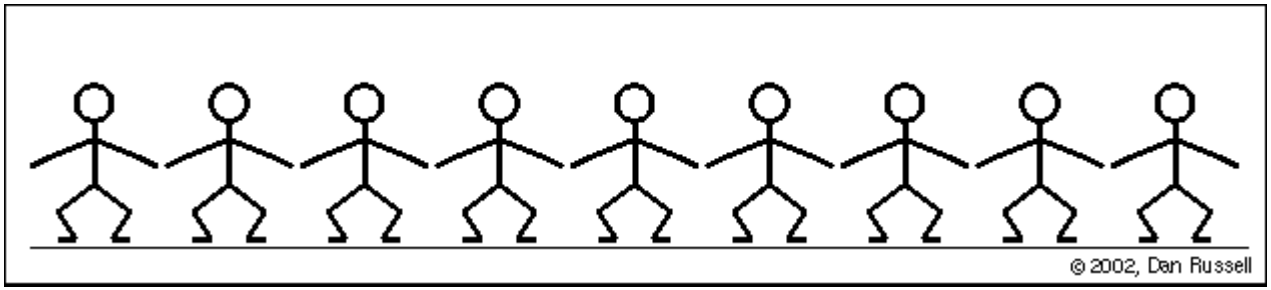
What is Sound?

- Sound is our perception of a medium being set in motion at certain frequencies
- When we create sound, we create vibrations that cause the air molecules around us to move
- These vibrations spread out from us, causing pressure waves as the molecules transfer energy by bumping into adjacent molecules

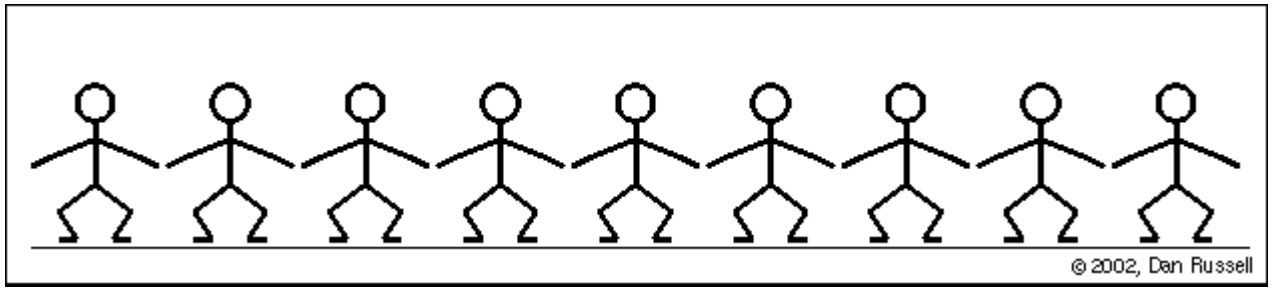
What is Sound?

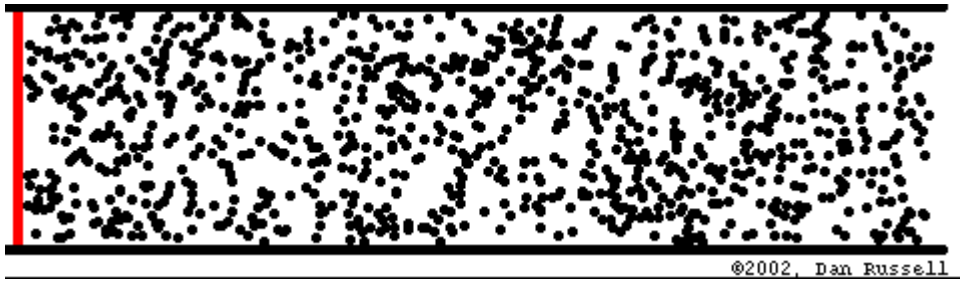
- Vibrations
  - Sound is a pressure disturbance that moves through a medium in the form of mechanical waves
  - Sound waves are made up of compressions and rarefactions



Waves

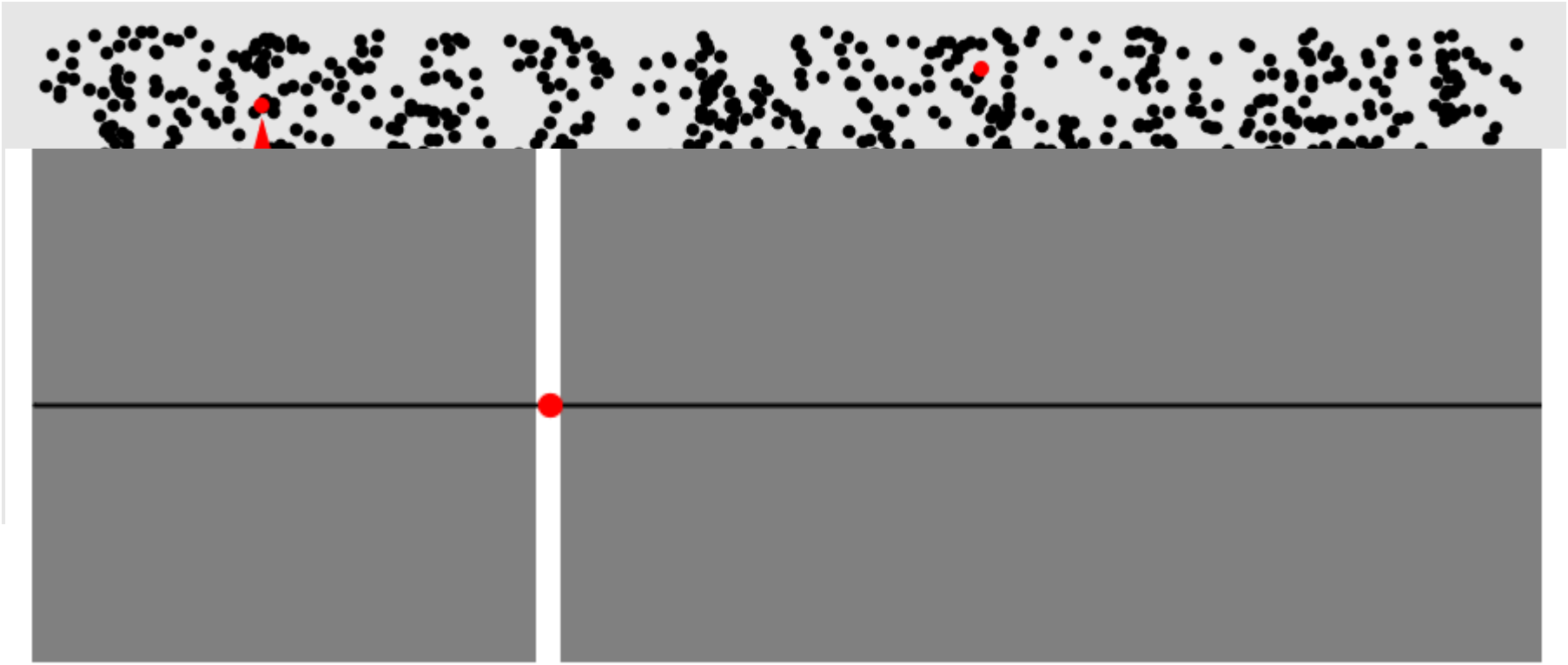
- Compression is when particles are pressed together
- Rarefaction is the opposite: the particles are given some extra space





Waves

- What do waves look like?



Vibrations

- How can we see that the fork is vibrating?
  - Get a tub of water
  - Get a tuning fork
  - Strike the tuning fork and dip it slowly into the tub of water
  - What happens?

How Do We Describe Waves?

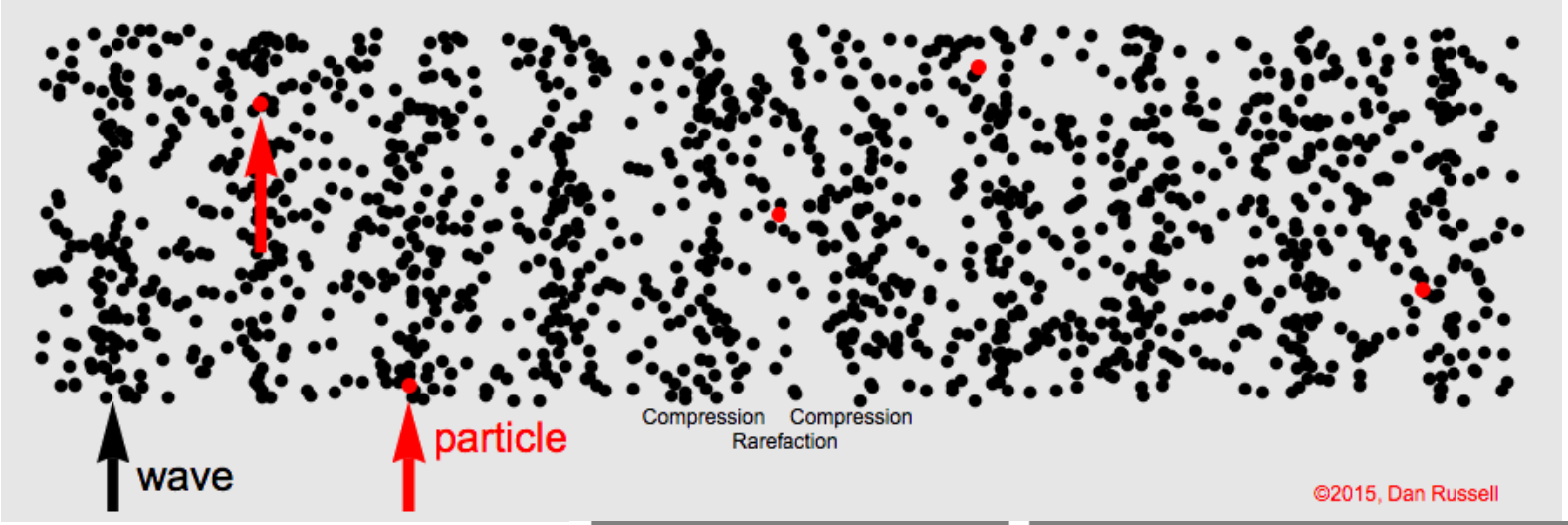
- Crests and Troughs
- Amplitude
  - A measure of the height of the wave a particular point
  - Typically we measure amplitude from peak-to-peak or from the x-axis
- Wavelength
  - Waves that repeat in a regular manner are called periodic
  - Each individual repetition is called a cycle
  - The distance from the start to the end of a cycle is a wavelength

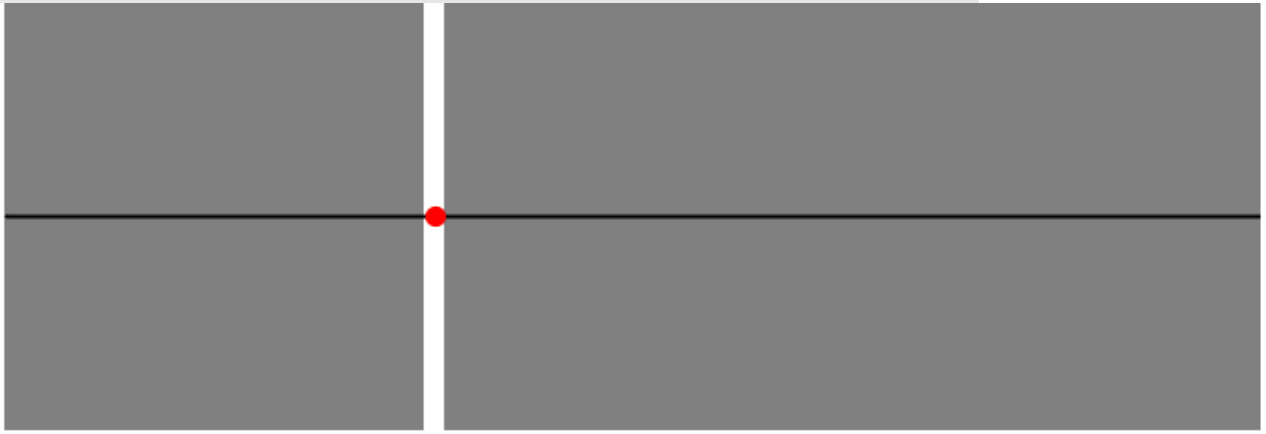
How Do We Describe Waves?

- Frequency
  - A measure of the number of cycles of a waveform that occur in a set time
  - Frequency is perceived as pitch
  - Measured in cycles per second (c.p.s.) or Hertz
- Period
  - The amount of time for something to complete on cycle/repetition
  - Period and frequency share an inverse relationship

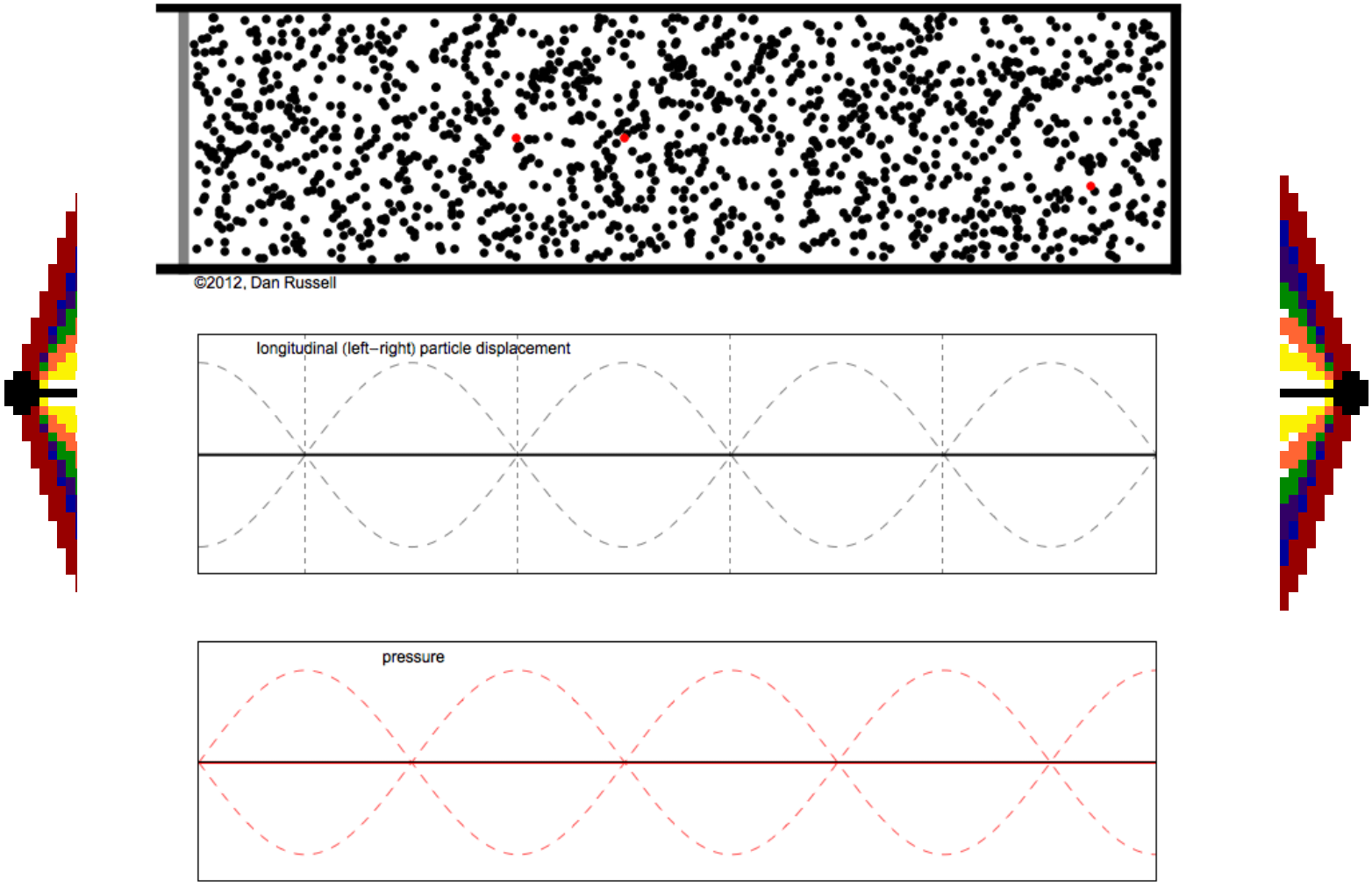
A Quick Note

- Travelling waves and standing waves





Standing Waves



The Speed of Sound

- The speed of sound at 20°C in dry air is approximately 343 m/s
- When a vehicle goes faster than the speed of sound, it is said to break the sound barrier and a sonic boom is produced

The Speed of Sound

- $v_s = \lambda f$

$$v_s = 343\ \frac{\text{m}}{\text{s}} \qquad f = 440\ \text{Hz}$$

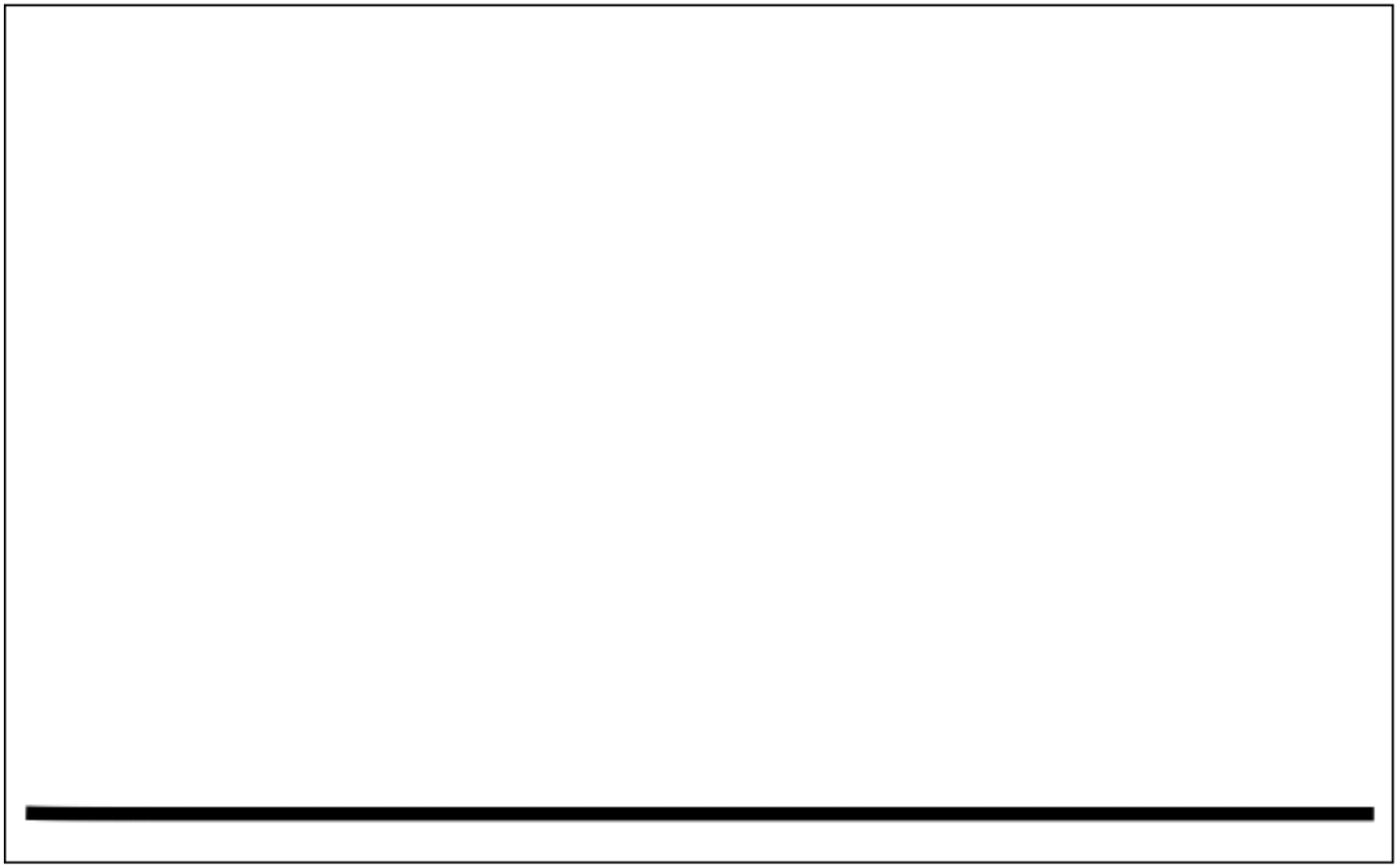
$$\frac{v_s}{f} = \lambda = \frac{343\ \frac{\text{m}}{\text{s}}}{440\ \text{Hz}}$$

$$= 0.78\ \text{m}$$

Interference

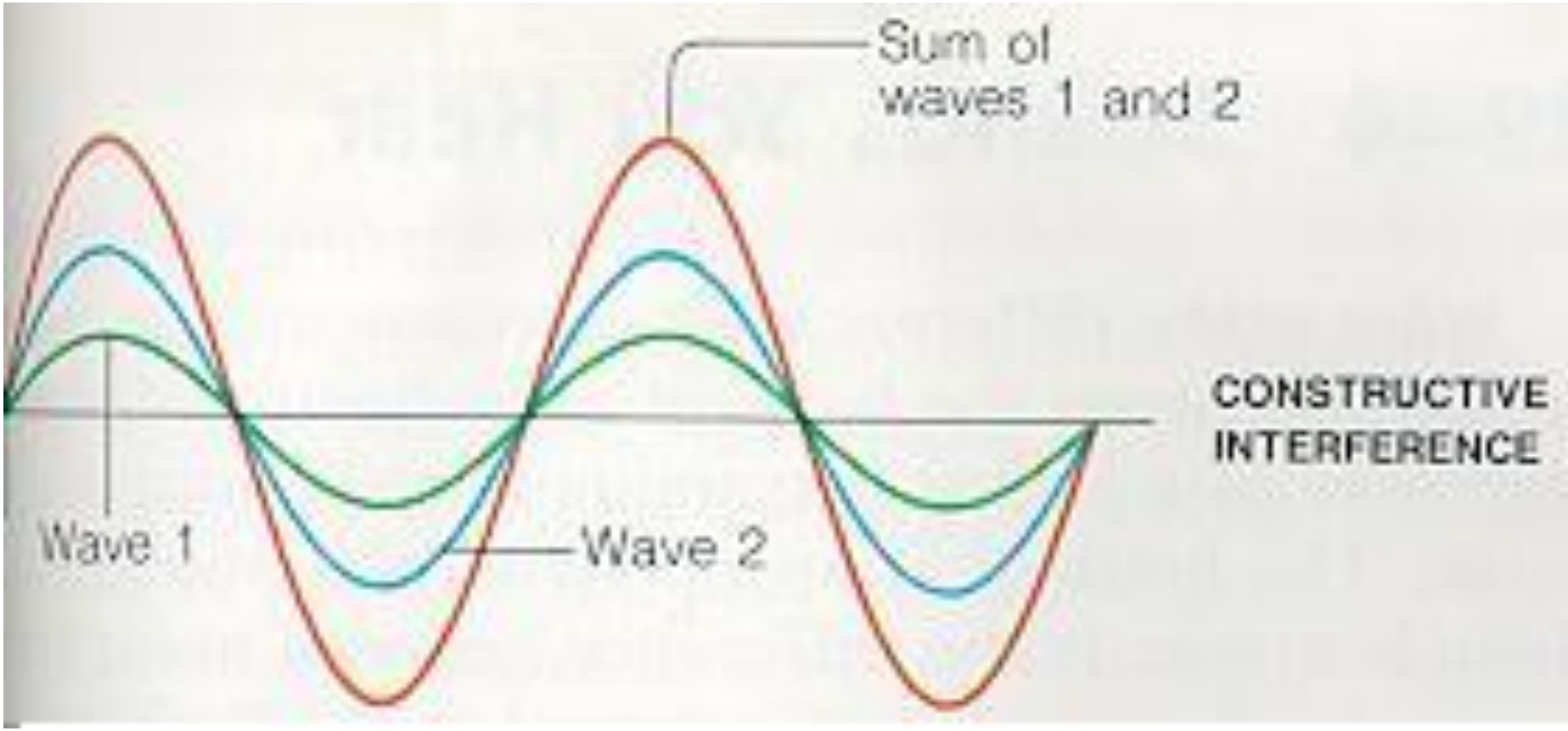
- When two or more waves interact with each other to produce a new wave
  - This new wave is the sum of the two waves
- When waves interact, it is known as interference
- This is called the Principle of Superposition
  - When two or more waves are in a medium, they may pass through each other without disturbing each other, but where they ‘collide’, the net displacement is the sum of the waves

Interference



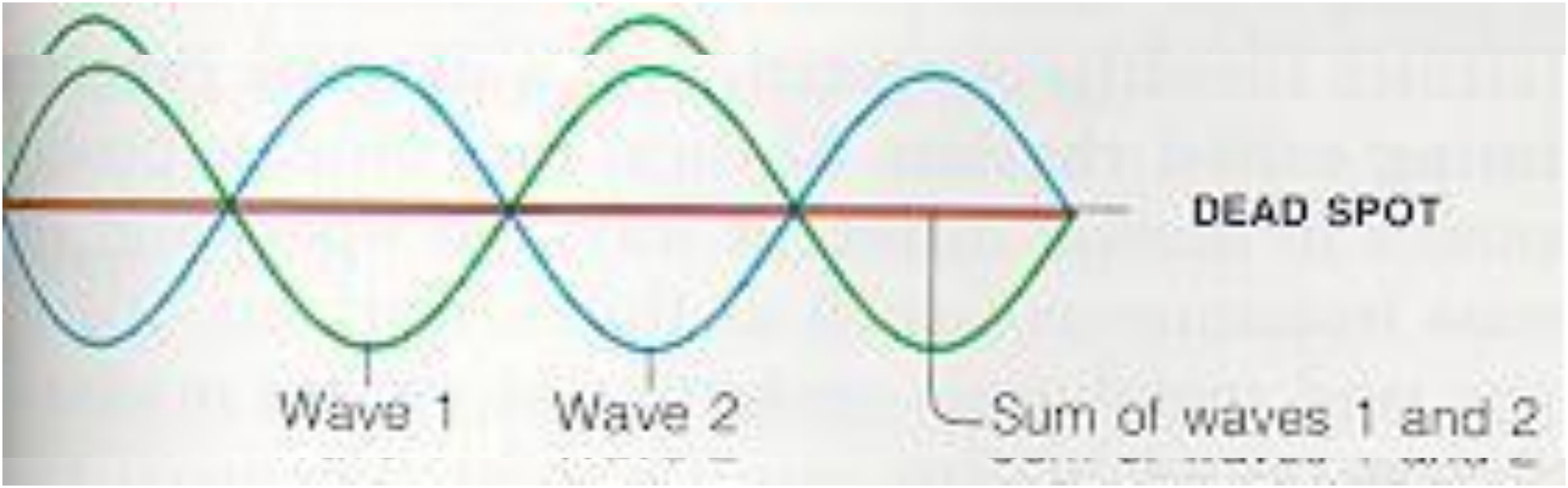
Interference

- When waves combine and become larger, this is known as constructive interference



Interference

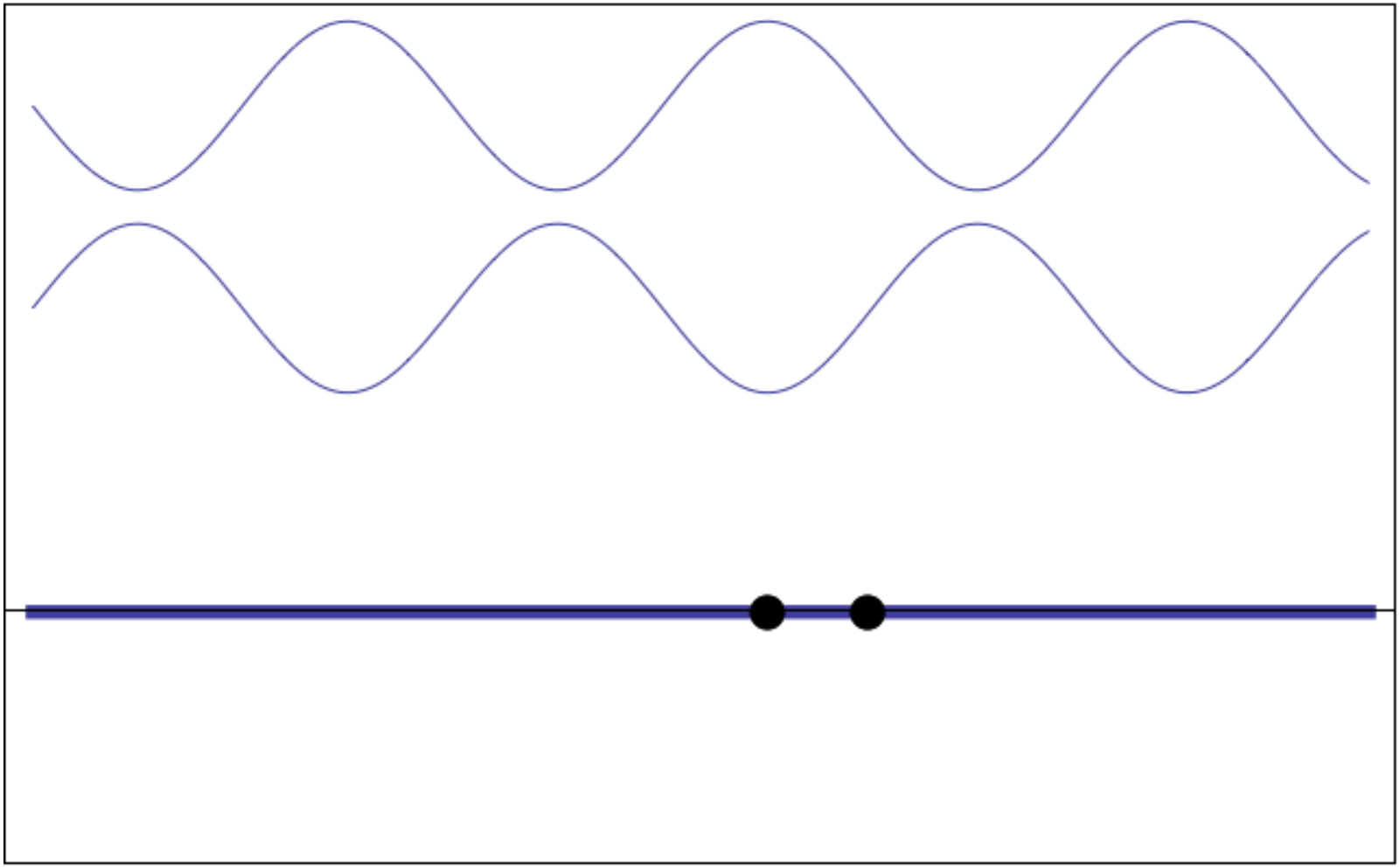
- When waves combine and don't line up, they create a weaker wave that is dampened or with a lower amplitude
  - This is destructive interference



Interference

- Constructive Interference
  - Waves add and strengthen to create a wave that is has more amplitude
- Destructive Interference
  - Waves cancel and create a weaker wave
  - Dead spots

Interference



Resonance

- Objects have natural frequencies and vibrate more easily at these specific frequencies
- When an object vibrates at its natural frequency, this is known as resonance
- Think of singers that can break wine glasses with their voices

Applications

- Music and music technology
- Buildings
- SONAR
- Medicine
- Psychology and Speech
- Oceanography
- Non-Destructive Testing

Active Noise Cancelling

- Pre-amplifier
- All-pass filter/delay
- Inverting summing amplifier