Wave Systems

ANSWERS

The Basics

The Basics

STOP AND CHECK (PAGE 8)

- The wave speed's units are ms^{-1}.
- Frequency is how many cycles occur in 1 second. The units for frequency are Hertz (Hz) or per second.
- A wavelength is the distance between the beginning of one wave and the beginning of the next wave (so between two troughs or two crests). It is measured in metres (m).
- The particles in a transverse wave move perpendicular to the velocity of the wave, which affects the displacement of the particles. The particles in a longitudinal wave move parallel to the direction of the wave's velocity, which affects the density of the particles.
- We draw longitudinal waves as transverse waves because it is easier to depict what is going on. We focus on density on the y-axis, rather than displacement.

Wave Behaviour

Phase Difference

STOP AND CHECK (PAGE 10)

- A phase difference is the difference between the same point on two different waves. It's measured as an angle, so in degrees or radians.

- They will be completely out of phase at 180 degrees and completely in phase at 0 or 360 degrees. Out of phase is when one trough occurs whilst one crest occurs. In phase, there are either 2 troughs or 2 crests at the same time.

Interference

STOP AND CHECK (PAGE 12)

- When waves run into each other, depending on if they are both up waves (in phase, crests), both down waves (in phase, troughs) or one of each (out of phase, 180°), the waves will either add to become a big wave or subtract and cancel each other out.
- A node is a point of no deflection/destructive interference. An anti-node is a point of constructive interference. You can remember this by thinking the "no" part in "node" corresponds to "no"thing or "no" "de"flection.
- Constructive
- Destructive

Beats

STOP AND CHECK (PAGE 14)

- Constructive interference is when two waves add together to make a larger wave. This happens when two troughs, two crests, or two points similar to each other are at the same point in time or space. Destructive interference is when two waves subtract from each other to create a smaller wave. This happens when a trough and a crest or two points with opposing amplitudes are at the same point in time or space.
- Their interference isn't constant so the phase difference ranges between constructive interference and destructive interference as the waves will sometimes be in phase and sometimes be out of phase with each other.
- $F_b = | f_1 - f_2 |$
- Beating occurs when 2 waves of similar frequencies interfere constructively (resulting in loud sound) and destructively (resulting in quiet sound and beats). As the guitar is tuned, its frequency becomes closer to that of the other wave, and so the difference in frequencies will decrease and the beat frequency will decrease.

Wave Behaviour

STOP AND CHECK (PAGE 14)

- When Jason and Jeffrey play their kazoos at the same time, their kazoos will produce sound waves of very similar frequencies. Because of this, beats will be created due to the constructive and destructive interference happening when the two waves meet. This will mean that there will be quiet and loud parts when they hear the note.
- $f_b = | f_1 - f_2 |$
    - $2 = 261 - f_2$
    - $f_2 = 261 - 2$
    - $f_2 = 259Hz$

  $v = f \times \lambda$
    - $343 = 259 \times \lambda$
    - $\lambda = \frac{343}{250}$
    - $\lambda = 1.372m$

Standing Waves

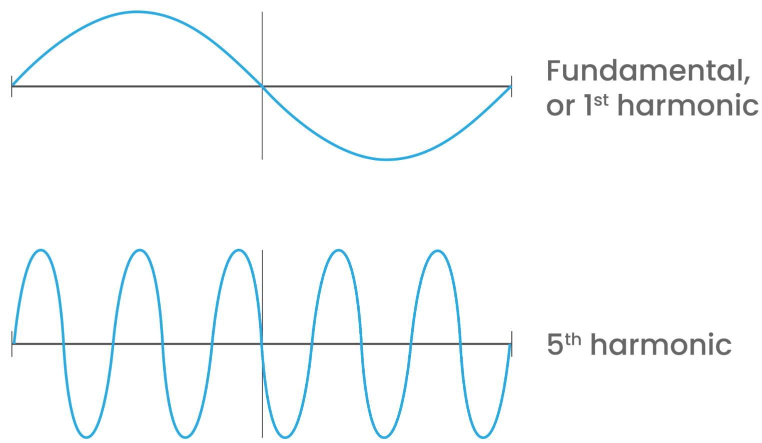
Strings

STOP AND CHECK (PAGE 16)

- We need 2 waves of the same frequency and size to come from opposite directions from each other and interfere.
- A node in a standing wave is the part with no deflection and an antinode is the part of the standing wave that is at maximum displacement (so a peak or a trough).

Making Music with Strings

STOP AND CHECK (PAGE 18)

- The frequency of the most basic wave that will stand in the conditions, called the first harmonic.
- Transverse waves will travel along the string and reflect and interfere with itself at the note at the end.
- Start by figuring out how many wavelengths fit into the length of string (e.g. ½ wavelength fits into one string length for the first harmonic). Make an equation for wavelength in terms of string length. Then, use this in the formula $v = f \times \lambda$ to find either speed or frequency.
- 

Making Music with Air

STOP AND CHECK (PAGE 22)

- Node.
- Antinode.
- The pipe with an open and a closed-end will produce the lowest note, as the first harmonic has a larger wavelength than that of the open-open pipe.

Standing Waves

QUICK QUESTIONS (PAGE 22)

- There are nodes at the two ends because the ends are fixed, so they don't move.

- There is an antinode where James is jumping because it is reaching maximum displacement.
- A standing wave is established because there are constant points of minimum and maximum displacement. His jumping caused two waves of the same frequency, speed, and amplitude but different directions to interfere.
- Using the wavelengths that we found in the walkthrough guide previously, we know that:
    - $\lambda_1 = 2L$ and
    - $\lambda_3 = \frac{2L}{3}$

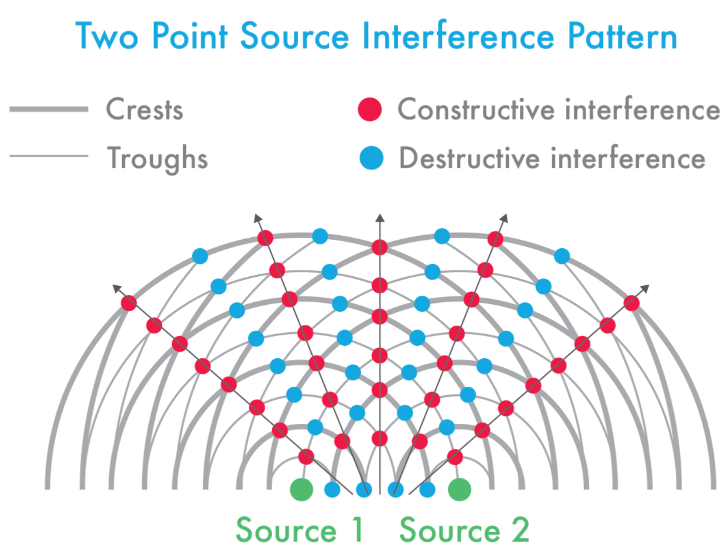
  If we put these into $v = f \times \lambda$ and rearrange, we get:
    - $f_1 = \frac{v}{2L}$ and
    - $f_3 = \frac{3v}{2L}$

  Which means that $f_3 = 3f_1$.

Two-Source Interference

Two Sources

STOP AND CHECK (PAGE 25)

- 

- A node.

- The sound will vary from loud to quiet as you walk through antinodes and nodes.

Diffraction

STOP AND CHECK (PAGE 25)

- The wavelength has to be similar in size to the gap that the wave is travelling through.

Double-Slit Experiment

STOP AND CHECK (PAGE 28)

- Dots of light along the wall will be produced. This is because as the light diffracts, it interferes with itself. Constructive interference results in light spots, whilst destructive interference results in dark regions.
- d = distance between slits,
    - n = number of fringes/dots counted from the centre (where centre = 0).
    - L = distance between slit grating and screen.
    - x = distance between light spots.
    - $\sin\theta$ = the angle a dot is diffracted from the centre.
    - λ = the wavelength.

Many Colours

STOP AND CHECK (PAGE 30)

- White light is comprised of all of the frequencies of visible light, which constructively interfere to form white light.
- The light still diffracts, just through more slits.
- Red, as it has the longest wavelength. This is proportional to the angle the wave is diffracted at, which will therefore be the largest.
- It is all constructive interference as there has been no angle of diffraction, so all the colours add together to produce white light.

Two-Source Interference

QUICK QUESTIONS (PAGE 30)

- The interference pattern is a line of dots of light with dark sections in between.
- White light is made up of all the frequencies of visible light. Because all of these frequencies are different, their wavelengths are different, which means that they all diffract at different angles. This means that they will be spread out when seen on the screen, creating the rainbow spectra. The violet is closest to the middle maxima because it has the highest frequency, which corresponds to the lowest wavelength. This means that it has the smallest angle of diffraction, putting it closer to the middle maxima than the other colours.
- Let's start this question by listing all of the values that we have and want to find:
  - L = 1.2m
  - x = 32cm or 0.32m
  - n = 4
  - $f = 4\times10^{14}$Hz
  - $v = c = 3\times10^{8}ms^{-1}$
  - d = ?

  Because we have L and need to find d, we can use $n\times\ \lambda = \frac{dx}{L}$
- First, we need to find λ using the frequency we've been given:
  - $v = f\times\ \lambda$
  - $\lambda = \frac{v}{f}$
  - $\lambda = \frac{3\times10^{8}}{4\times10^{14}}$
  - $\lambda = 7.5\times10^{-7}$m

  Now, using this to find d:
  - $n\times\ \lambda = \frac{dx}{L}$
  - $d = \frac{Ln\times\lambda}{x}$
  - $d = \frac{1.2\times4\times7.5\times10^{-7}}{0.32}$
  - $d = 1.125\times10^{-5}$m

Doppler Effect

Doppler Effect

STOP AND CHECK (PAGE 32)

- Higher.
- Lower
- We plus when the distance between source and observer is increasing and subtract when this distance is decreasing.
- The Doppler Effect is what happens when something is producing sound and it is either moving towards or away from you. What happens is that the sound waves either get pushed or pulled by the moving source, and their wavelength appears to either get bunched up or spread out. A change in wavelength means a change in frequency, so the sound you hear is different. This is why when an ambulance passes you, the sound of the siren changes from before it passes you to after.

Doppler Effect

QUICK QUESTIONS (PAGE 32)

- Josh is hearing the actual frequency of the horn because the waves aren't being distorted from his position. This is different from someone standing still because the waves would either squish up or stretch out when they reach them, depending on whether the bike is moving towards or away from them.
- First, we should list the values we have:
    - $v_w = 343ms^{-1}$
    - $f'_1 = 61Hz$
    - $f_2 = 67Hz$
    - $v_s = ?$
- We know that the value of f doesn't change, so we can equate f in the Doppler Effect equations and rearrange to find:
    - $V_s = v_w(\frac{f'_1 - f_2}{-f'_1 - f'_2})$

- $v_s = 343(\frac{61 - 67}{-61 - 67})$
- $v_s = 343(\frac{6}{128})$
- $v_s = 16ms^{-1}$