



# INTERFERENCE AND RESONANCE

PES 1000 – PHYSICS IN EVERYDAY LIFE

# STRING PULSE: REFLECTION

**Fixed end:** Imagine a string (under tension) attached to an eye-hook on a wall. You flick the loose end to send an **upward pulse** toward the wall.

- When the pulse reaches the eye-hook, the **energy** in the pulse **bends the hook up** slightly.
- The hook is **spring-like**, so it **rebounds**, causing a pulse that returns to you, but is **downward**, or inverted.

**Loose end:** Now picture the string tied to a ring that is free to slide up and down a rod.

- When the pulse reaches the ring, it **lifts** the ring up against **gravity**.
- The energy in the ring is returned to the string when the ring **falls back down**, causing a pulse that returns to you **upward**, or upright.



# STRING PULSE: REFLECTION AND TRANSMISSION

Picture two **strings of different mass**, connected at the ends and put under tension. A pulse approaching the interface will encounter an end that is somewhere **between fixed and loose**.

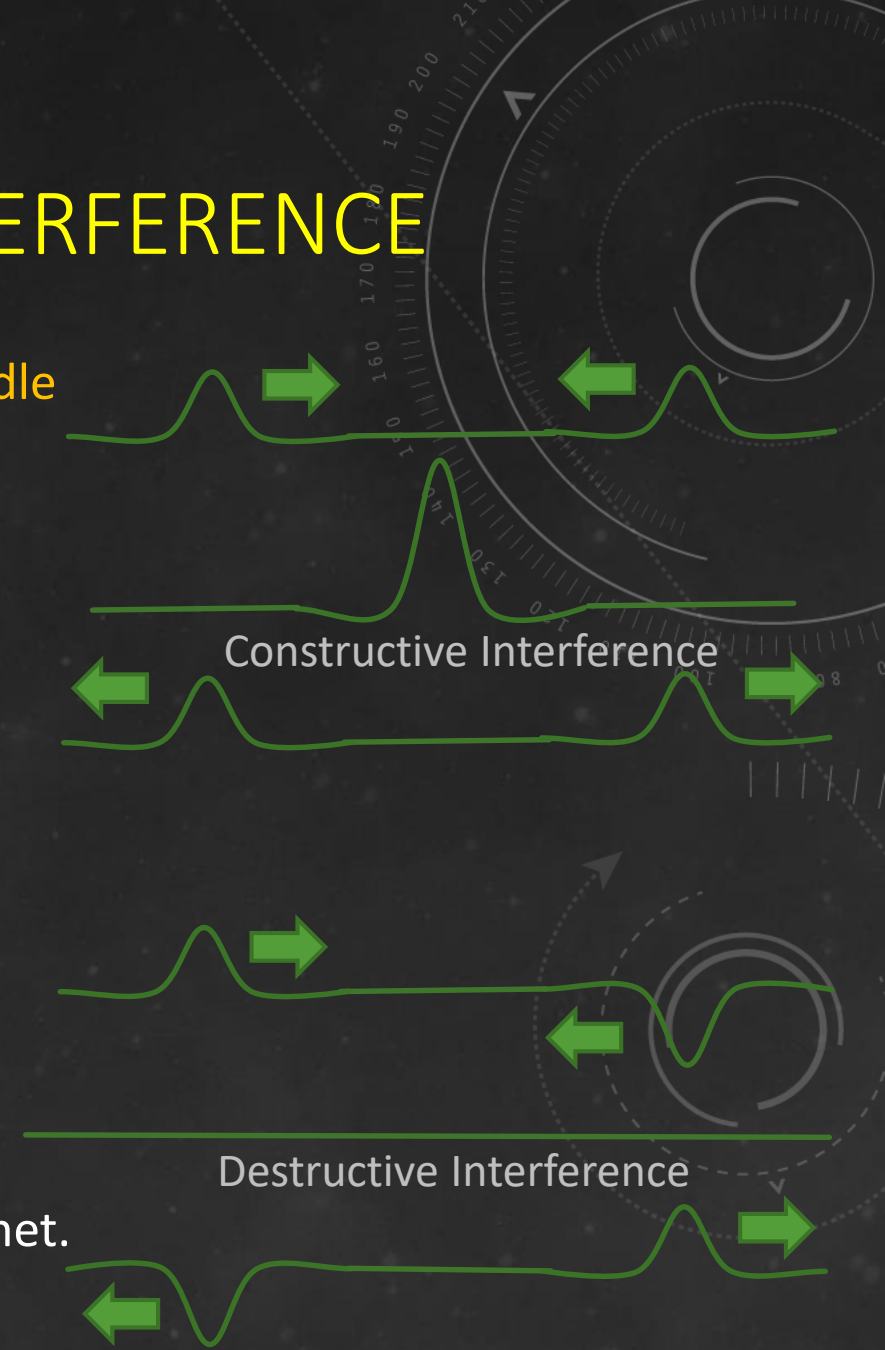
- If the **first string is lighter** than the second...
  - ... the transition is more like the fixed end than it is like the loose end.
  - The pulse in the first string is **reflected** but is **inverted**.
  - Some of the energy is **transmitted** to the second string, causing a pulse to continue through it (**upright**).
- If the **first string is heavier** than the second...
  - ... the transition is more like the loose end than it is like the fixed end.
  - The pulse in the first string is **reflected** and is **upright**.
  - Some of the energy is **transmitted** to the second string, causing a pulse to continue through it (**upright**).



# CONSTRUCTIVE AND DESTRUCTIVE INTERFERENCE

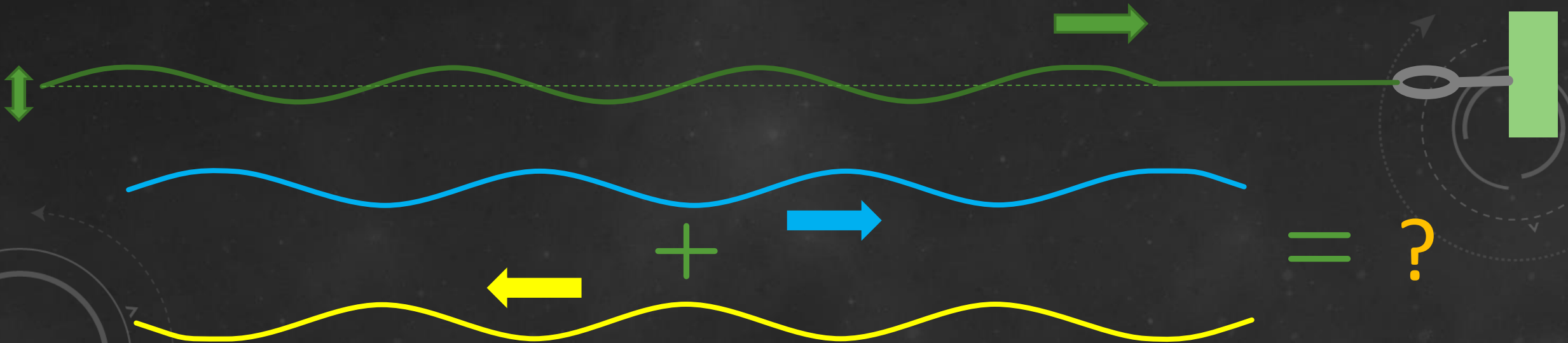
If we have a string under tension, and we send **pulses toward the middle** from either end, **what happens when they meet?**

- If **both pulses are upright**...
  - ...the energy they contain when they meet **adds together** on the same side of the string to create a larger upright pulse.
  - This is called **constructive interference**.
  - Afterward, the pulses continue on as if they had never met.
- If **one pulse is upright and the other is inverted** ...
  - ...the energy they contain when they meet **cancels out**, leading to **no pulse** at all for an instant.
  - This is called **destructive interference**.
  - Afterward, the pulses continue on, again as if they had never met.



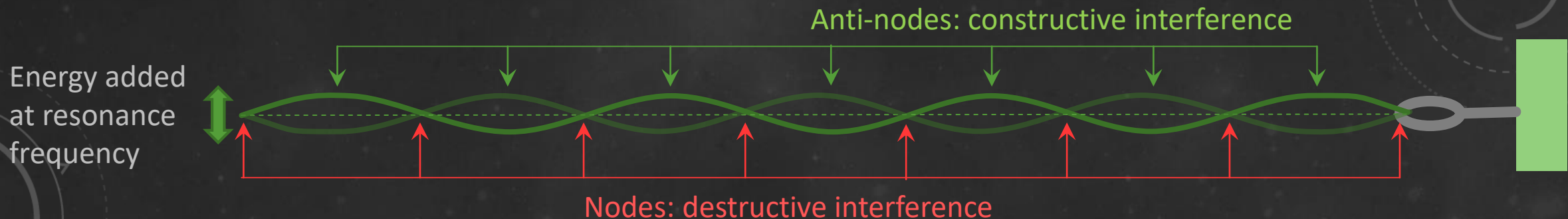
# PERIODIC (SINUSOIDAL) WAVES

- Let's attach a string to a fixed end, put it under tension, and send a periodic series of pulses along it, so as to form a **sinusoidal wave**.
- The fixed end will reflect the energy of the wave back, but inverted.
- The **reflected wave will interfere with the incoming wave**.
- The resulting **interference pattern** (constructive and destructive) **depends on the wavelength** (or frequency) of the wave.



# RESONANCE IN A STRING

- If the total **length of the string** is an exact **multiple of half-wavelengths** of the wave, then that wavelength 'fits' on the string.
- The wave is said to '**resonate**' on the string.
- The places where **constructive** and **destructive** interference occurs on the string are fixed.
  - At certain locations on the string, wave pulses traveling in opposite directions **constructively interfere**, making the string deviate from equilibrium the most. These points are called **anti-nodes**.
  - Between each anti-node, the oppositely moving wave pulses **destructively interfere**, causing the string to not deviate from equilibrium at all. These points are called **nodes**.
- This pattern forms what is called a '**standing wave**'.



# ANOTHER RESONANCE CASE

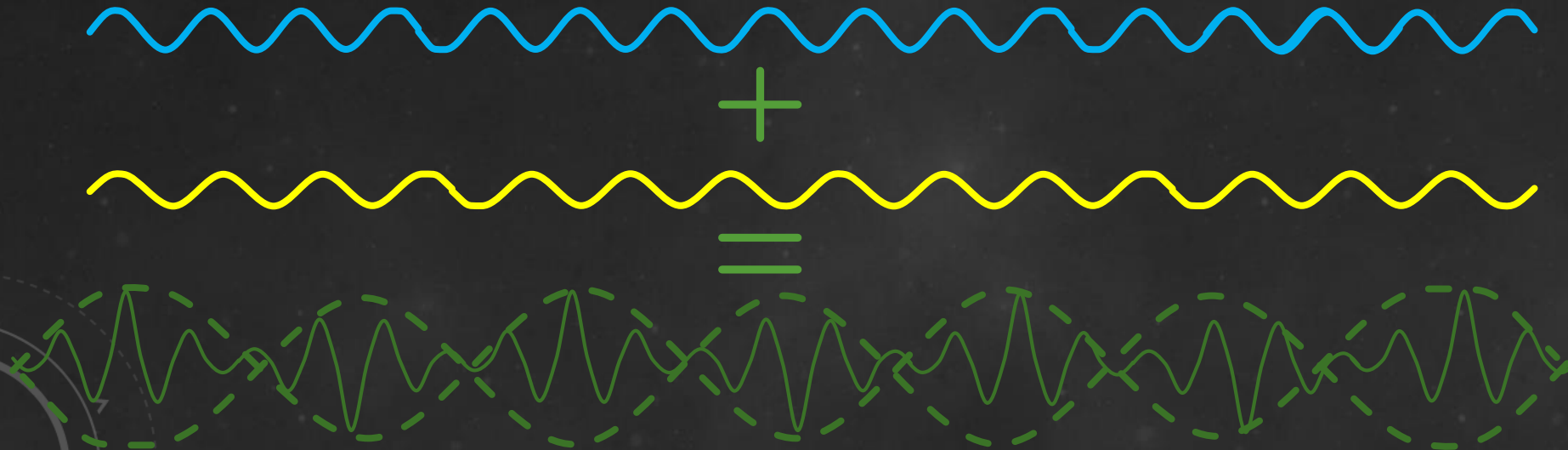
Sound waves within a closed chamber (Example: singing in the shower)

- Certain frequencies have a wavelength that **'fits'** into the chamber, meaning the chamber is an **integer number of wavelengths** in length.
- These frequencies will **constructively interfere** with each other, causing that pitch to **'resonate'** or **'swell'**.
  - That pitch is louder and seems to come from all directions at once, compared to other pitches.
- Energy added at the 'right' frequencies **constructively adds**, or magnifies.
- Energy added at the 'wrong' frequencies **decays** away.
- There are many 'right' frequencies because many different length waves can fit in the same chamber



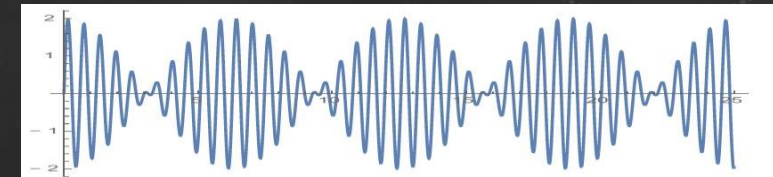
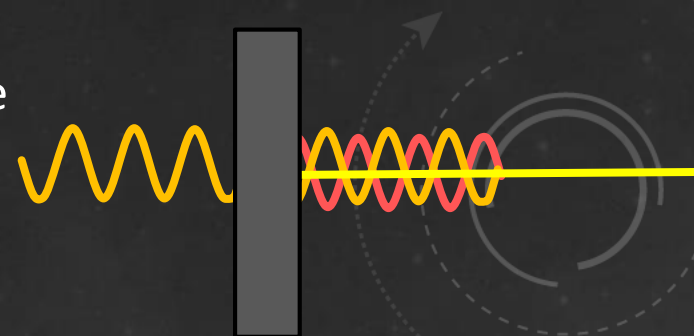
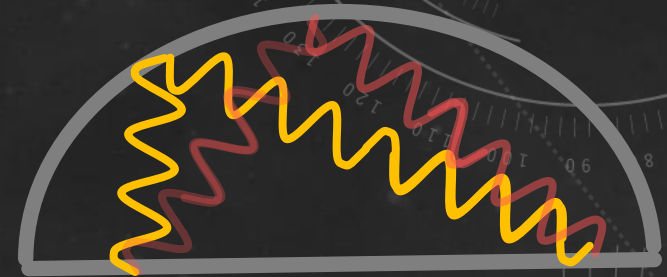
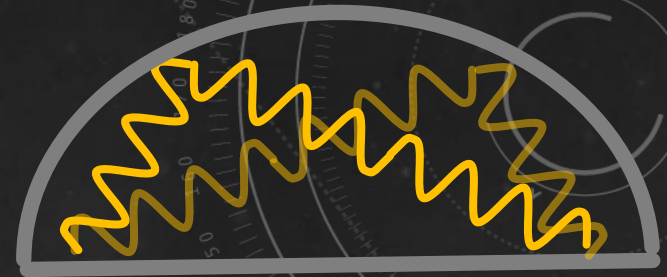
# BEAT FREQUENCIES

- When two waves that **differ only slightly in frequency** are added together, the result is a **complicated wave** that has regions of constructive interference with regions of destructive interference between.
- The composite interference pattern has a **longer wavelength** than either of the two original waves. The corresponding lower frequency is called a '**beat frequency**'.
- The **closer the two original frequencies**, the **longer the beat frequencies wavelength**.



# OTHER APPLICATIONS OF INTERFERENCE

- **Resonant zones** in a chamber
  - Sound from a source reflects and **constructively adds** at another spot.
  - (See [National Statuary Hall](#) in Washington D.C.)
- **'Dead' spots** in an auditorium
  - Sound from a source reflects and **destructively cancels** at another spot.
- **Noise-cancelling** headphones
  - An input noise is duplicated but 'flipped' by the electronics, causing the sum of original noise and 'flipped' noise to be **nearly cancel**.
- **Tuning a piano**
  - Most notes in a piano are made by two strings with the same natural frequency.
  - If the **two strings are slightly different**, a **beat frequency** can be heard. One string is tightened until the beat frequency disappears.



# CONCLUSION

- The **energy** in a wave can be **reflected** and/or **transmitted** at boundaries.
- Energy from different waves can add **constructively** (increasing the amplitude) or **destructively** (decreasing the amplitude).
- If the interacting waves have the correct wavelength (and frequency) within a contained vibrating medium, they will **resonate**.
  - One or more parts of the medium will have **maximum vibration (anti-node)**
  - On either side of an anti-node will be a **node**, where the medium **doesn't vibrate** at all.
- Waves with **slightly different frequencies** will combine to have a long-wavelength **beat frequency**.
- **Interference effects** can be used to **improve and modulate** the effects of sound waves.

# Image attributions

None:

