PHY131H1F - Class 33

- A wave involves a disturbance, or pattern, that moves through space.
- The disturbance carries energy, but not matter.
- Just as a wave can travel across a field of wheat without the wheat moving across the field, sound energy can move from my mouth to a listener's ear, without the air particles actually moving that distance.

Today:

11.4 Wave Intensity, 11.7 Intensity Level (Decibels)

11.5 , 11.6 Superposition Principle for Waves, Wave Interference, Intro to Standing Waves

1

Poll

Crazy Friday: Let's Choose a Filter my face today

Well I got Snap Camera let's try it today…

A. My Twin (me as a girl)

D. Cowboy

B. Anime Style

E. Pink Hairstyle

C. Santa by Mana Mans

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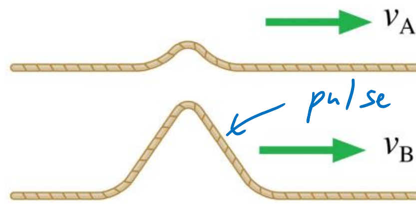
Poll Question

These two wave pulses travel along the same stretched string, one after the other. Which is true?



A. $v_A > v_B$

B. $v_B > v_A$

C. $v_A = v_B$ (circled)

D. Not enough information to tell.

→ wave speed does not depend on amplitude.

$v = \sqrt{F/\mu}$

F = tension

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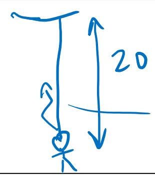
An 80 kg climber hangs from a rope, 20 m below a rocky overhang. The rope has a linear density of 37 g/m.

Approximately how long would it take a transverse pulse to travel the length of the rope from the climber to the overhang?

SKETCH & TRANSLATE.



$m = 80$ kg

$\mu = 37 \times 10^{-3}$ kg/m

$t = ?$

SIMPLIFY & DIAGRAM

system = climber. Assume constant speed.

+y

$\vec{T}_{rope}$

$\vec{F}_{g\,E\,on\,c}$

$\Sigma F_y = 0 = T - mg \Rightarrow T = mg$

Let's call this $F = mg$

wave speed $v = \sqrt{F/\mu}$

REPRESENT MATHEMATICALLY

$v = \frac{d}{t} \Rightarrow t = \frac{d}{v} = d\sqrt{\frac{\mu}{mg}}$

SOLVE & EVALUATE

$t = 20\sqrt{\frac{37 \times 10^{-3}}{80 \cdot 9.8}}$

$t = 0.14$ s

We neglected the mass of the rope. $m_{rope} = 20\,m(37 \times 10^{-3})$

$m_{rope} = 0.7$ kg

this is a lot less than 80 kg

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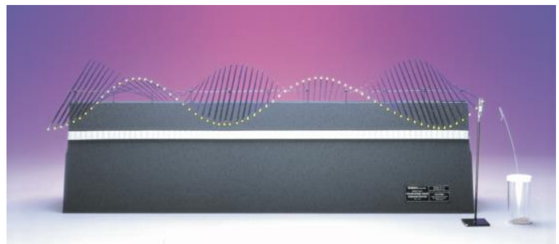
Demonstrations today:

1. "**Wave Machine"** – parallel metal bars all connected by a common spine which can twist.



2. Rubber Hose.

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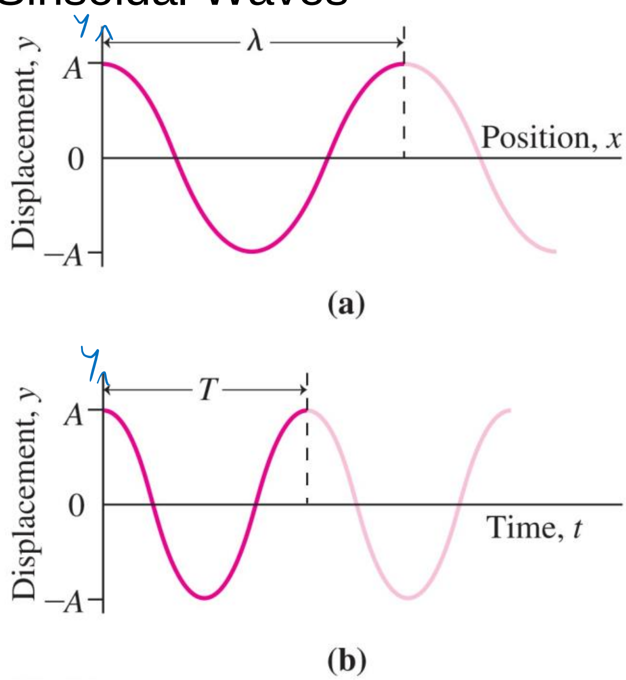
Properties of Sinsoidal Waves

- **Wavelength** λ is the distance over which a wave repeats in space.
- **Period** T is the time for a complete oscillation of the wave at a fixed position.
- **Frequency** f is the number of wave cycles per unit time: $f = 1/T$
- **Amplitude** A is the maximum value of the wave disturbance.



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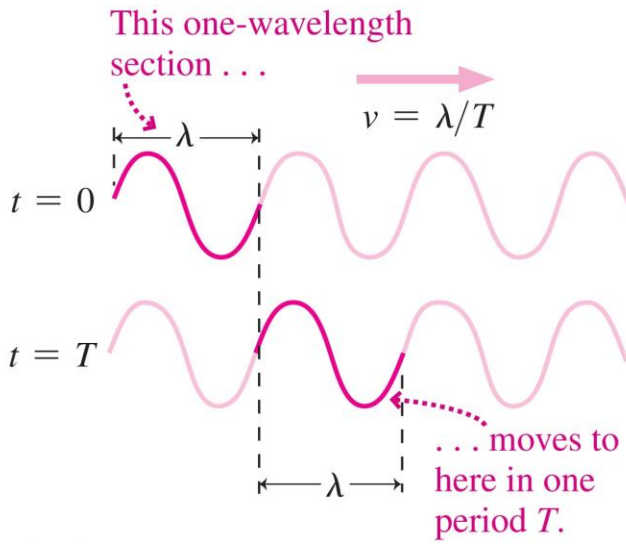
Wave Speed

- **Wave speed** is the rate at which the wave propagates.
- Wave speed, wavelength, period, and frequency are related:

$$v = \frac{\lambda}{T} = \lambda f$$



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Quick Poll – 20 seconds!

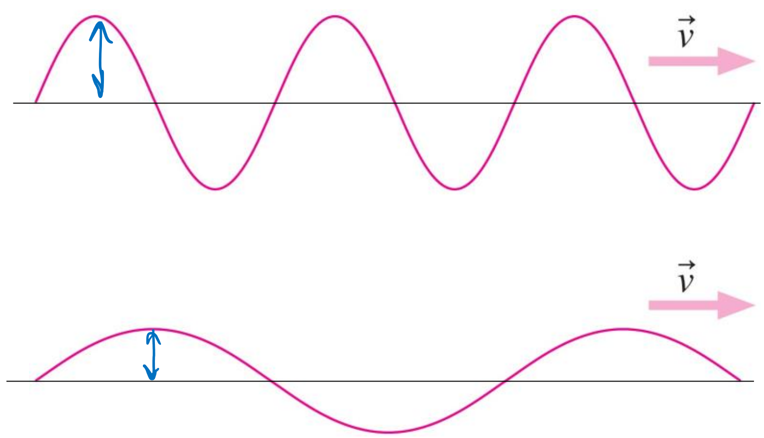
- Here are snapshots (y vs x) of two waves that have the same speed.
- Which has the greater **amplitude**?

$v = \lambda f$

$\lambda = \frac{v}{f}$

A

B



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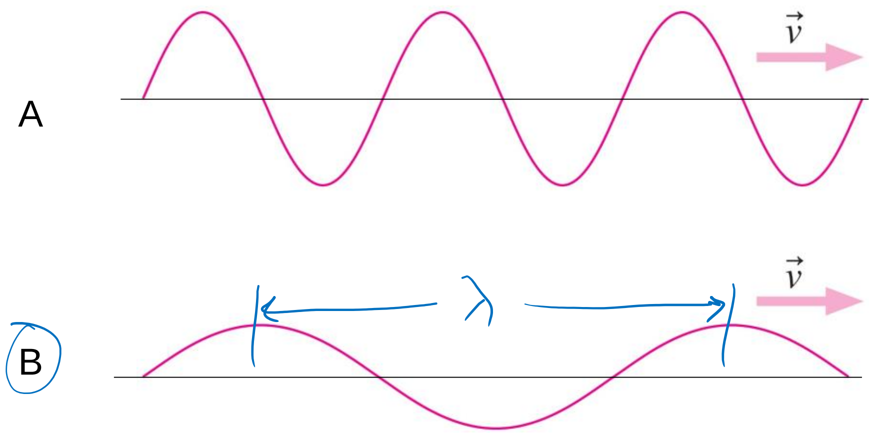
Quick Poll – 20 seconds!

- Here are snapshots (y vs x) of two waves that have the same speed.
- Which has the greater **wavelength**?

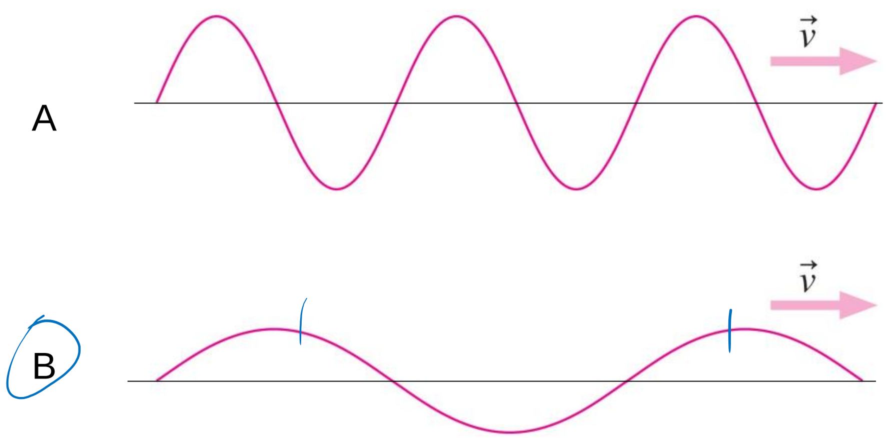


Quick Poll – 20 seconds!

- Here are snapshots (y vs x) of two waves that have the same speed.
- Which has the greater **period**?

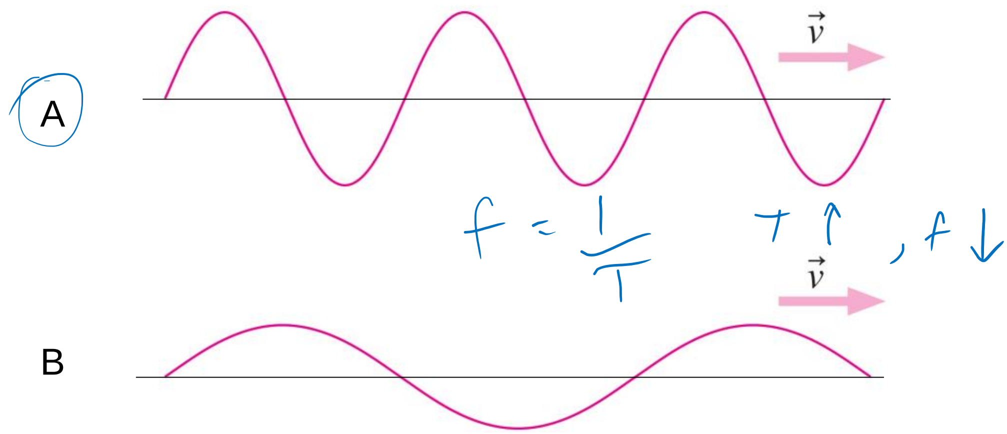
$v = \frac{\lambda}{T}$ $\quad T = \frac{\lambda}{v}$

$\lambda \uparrow, \; T \uparrow$



Quick Poll – 20 seconds!

- Here are snapshots (y vs x) of two waves that have the same speed.
- Which has the greater **frequency**?



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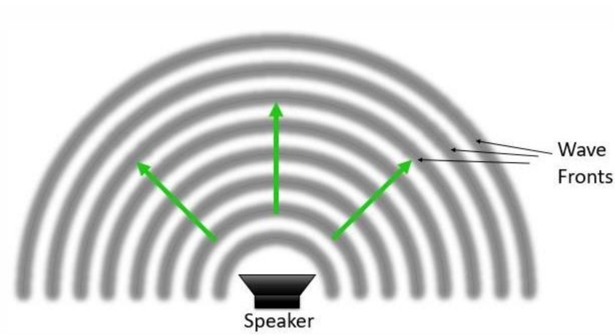
Wave Intensity

- A speaker emits a certain power in **Watts**. (Joules per second)
- The wave fronts are spheres (or hemispheres) each with a certain surface area in metres^2.



$$Intensity = \frac{Power}{Area}$$

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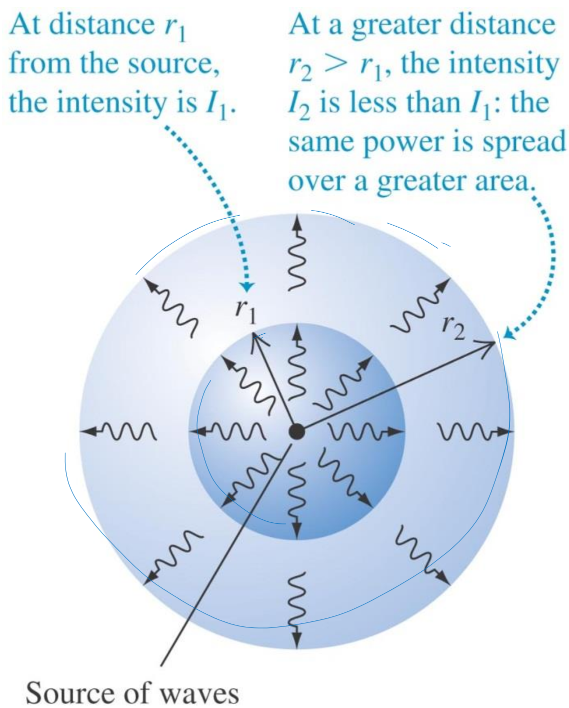
Wave intensity

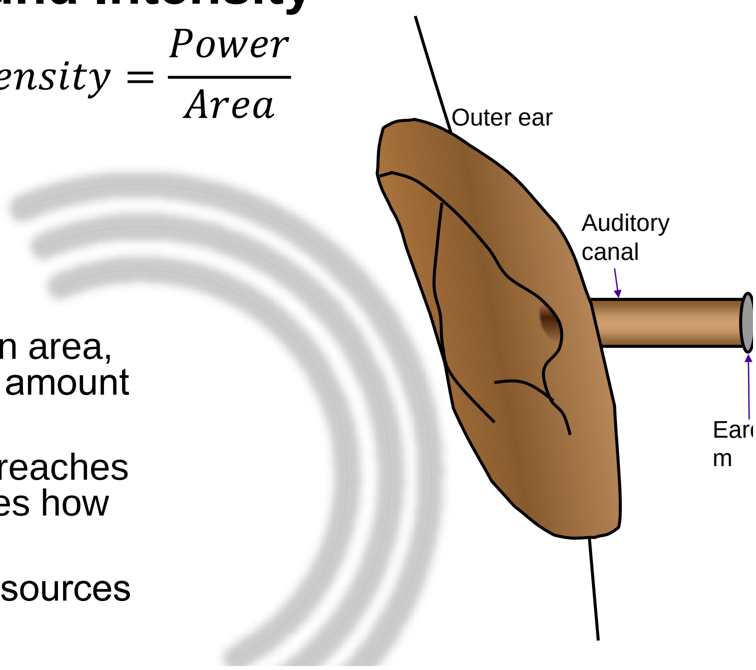
- The *intensity* of a wave is the average power it carries per unit area.
- If the waves spread out uniformly in all directions and no energy is absorbed, the intensity I at any distance r from a wave source is inversely proportional to r^2.



Sound Intensity

$$Intensity = \frac{Power}{Area}$$

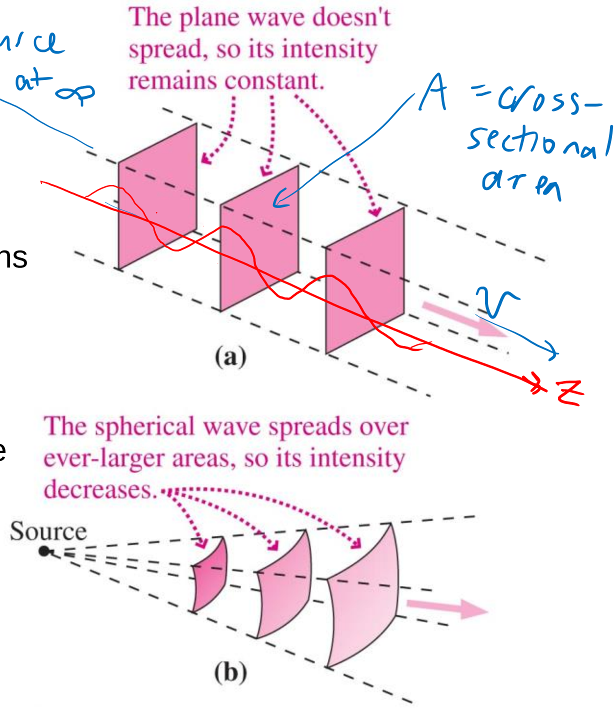
- Our eardrum has a certain area, which “catches” a certain amount of power.
- So, it is the intensity that reaches our head which determines how loud a sound is.
- That’s why further sound sources seem quieter to us!



Wave Intensity

- Wave **intensity** is the power crossing a unit perpendicular area.
  - In a **plane wave**, the intensity remains constant.
  - A **spherical wave** spreads in three dimensions, so its intensity drops as the inverse square of the distance from its source:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$



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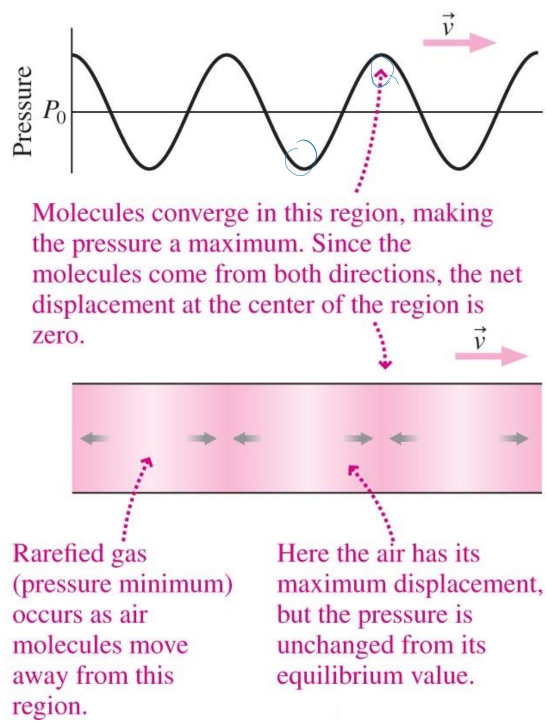
Sound

- Sound waves are longitudinal mechanical waves that propagate through gases, liquids, and solids.
- Sound waves in air involve small changes in air pressure and density, associated with back-and-forth motion of the air as the wave passes.



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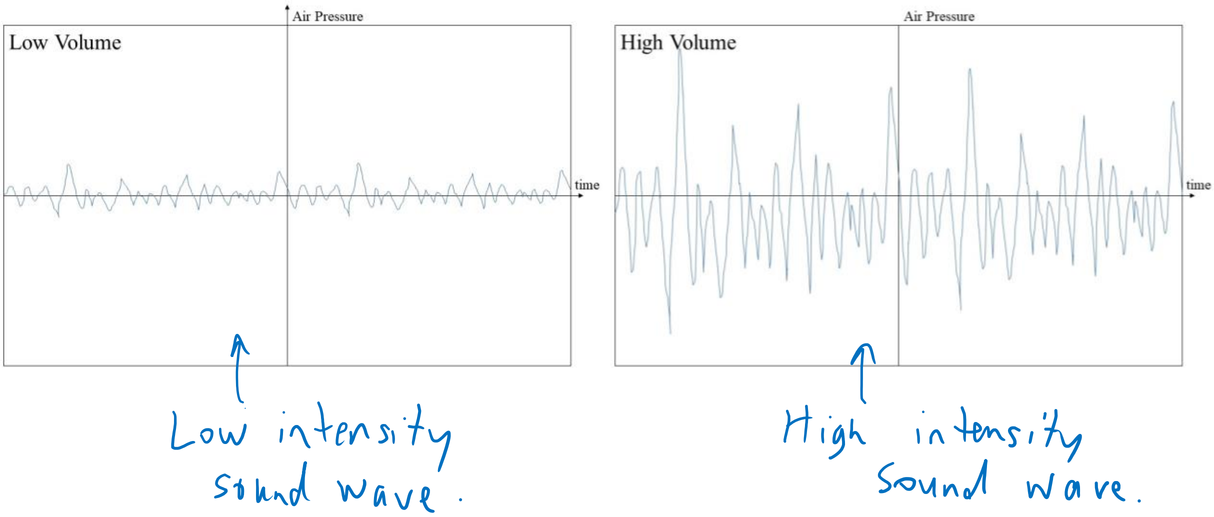
Volume



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Sound Intensity Level

- The decibel (abbreviated dB) is the unit used to measure the **sound intensity level** of a sound.
- The decibel scale is a little odd because the human ear is incredibly sensitive.
- Your ears can hear everything from your fingertip brushing lightly over your skin to a loud jet engine.
- In terms of **intensity**, the sound of the jet engine is about 1,000,000,000,000 times more powerful than the smallest audible sound. That's a big difference!

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Human Hearing and the Decibel

- For a sound with an intensity I in $\mathrm{W/m^2}$, the sound intensity level β is defined as:

$$b = 10\log\left(I/I_0\right)$$

- The unit of β is called decibels, abbreviated dB.
- In this equation, I_0 is a reference intensity:

$$I_0 = 10^{-12}\ \mathrm{W/m^2}$$

← corresponds to the quietest sound we can hear.

$\log_{10}(1) = 0$ (zero dB).

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Sound Intensity Level

- On the decibel scale, the smallest audible sound (near total silence) is 0 dB.
- A sound 10 times more powerful is 10 dB.
- A sound 100 times more powerful than near total silence is 20 dB.
- A sound 1,000 times more powerful than near total silence is 30 dB.

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Sound Intensity Level

Source	Intensity (Milliwatts / m^2)	Sound Intensity Level
Jackhammer operator	10,000	130 dB
Threshold of Pain	1000	120 dB
Live Rock Music	100	110 dB
Live Symphony Music	10	100 dB
Chamber Music in Small Auditorium	1	90 dB
Normal Piano Practice	0.1	80 dB
Soft Radio Music in a Home	0.01	70 dB
Normal conversation with two people	10^{-3}	60 dB
Refrigerator humming 1 m away	10^{-4}	50 dB
Library	10^{-5}	40 dB
Background In a Good Recording Studio	10^{-6}	30 dB
Rustling leaves 10 m away	10^{-7}	20 dB
A watch ticking 1 m away	10^{-8}	10 dB
Threshold of Hearing	10^{-9}	0 dB

$$b = 10\log\left(I/I_0\right)$$

Note:
Every ***multiplicative*** factor of x10 in Intensity corresponds to an ***additive*** +10 decibels to the Sound Intensity Level.

louder.

$= 10^{-12}\ W/m^2$

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Crazy Friday TV Show Bracket Today: Final

After the Team-Up Quiz we will be having a quick (15 seconds) poll to determine the best TV show.

- Queen’s Gambit

VS

- The Good Place

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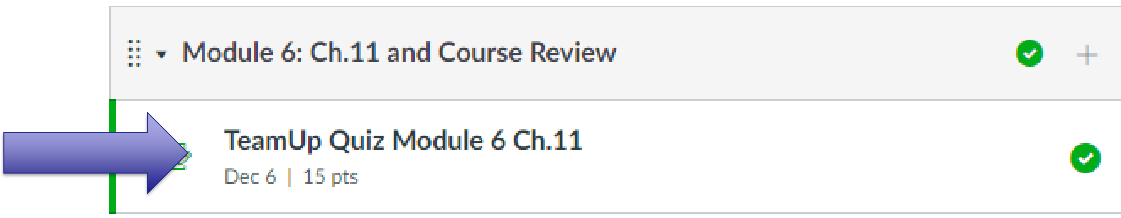
TeamUp Time!!

- Today you will be doing three multiple choice questions, all from Chapter 11, as a team of 2-4 students in your Practicals Pod.
- Your pod-team shares the mark!
- Right now you should open Microsoft Teams and someone (most recent Facilitator) should place a **video call** to all 3 or 4 members of your Pod-Chat.



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Now: TeamUp! You have 10 minutes

- The first step is to decide who will be the TeamUp **Driver**
- All students must log-in to Quercus [You will now have three windows open: my zoom lecture, Microsoft Teams, and Quercus]

End Time: 11:53

- **Non-drivers**: Wait!
- **Driver**: Go to the TeamUp Quiz Ch.11 in Module 6, click Go to Tool, then Create a Group. Let everyone in the Breakout Room know the session ID. Then WAIT – don't drive off alone!
- **Non-drivers**: Once you get the session ID, go to the TeamUp Quiz in this module, click Go to Tool, then Join Session and type the ID you were given.
- Once everyone in your room arrives in TeamUp, start going through the questions. Please **achieve consensus** before the driver submits.
- YOU MAY BEGIN! I'm going to go on mute for 10 minutes. Note: if your pod-mates are available on Microsoft Teams right now, go to the PHY131 Help Centre and I'll set up breakout rooms there. Zoom Meeting ID: 938 0964 2256, Passcode: 723874

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Crazy Friday TV Show Bracket
Today: Final

15 second poll. Which do you prefer?

A. Queen's Gambit

B. The Good Place

33%

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Question 1 Discussion

One singer produces an intensity of 0.1 milliWatts/m2 when she sings a distance of 3 m from a listener. If you get 10 singers together who sing at the same volume at the same distance, what will be the intensity the listener hears?

A. 1 milliWatt/m2
B. 1.1 milliWatts/m2
C. 10.1 milliWatts/m2
D. 11 milliWatts/m2

Intensity [W/m²] is the energy. 10 singers should produce 10 × the energy per second per area.

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Question 2 Discussion

One singer produces a sound intensity level of 80 dB when she sings a distance of 3 m from a listener. If you get 10 singers together who sing at the same volume at the same distance, what will be the sound intensity level the listener hears?

A. 81 dB
B. 90 dB
C. 100 dB
D. 800 dB

$\times I$ by 10

$\Rightarrow +\beta$ by 10

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Question 3 Discussion

When you turn up the volume on your earbuds, the sound originally entering your ears at 50 decibels is boosted to 80 decibels. By what factor is the intensity of the sound has increased?

A. 30
B. 100
C. 300
D. 1000

50
↓ 3 "steps" of +10
80

so 3 factors of 10 in intensity.

$10 \times 10 \times 10 = 1000$

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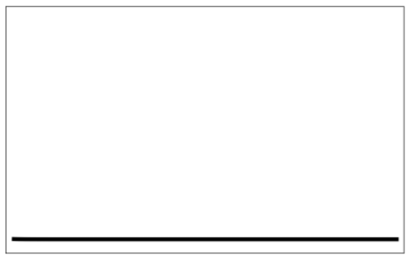
Particles and Waves

- Particles cannot occupy the same space. They **collide**.

- Waves pass right through each other. They **interfere**.



[Animations from http://www.physicsclassroom.com/mmedia/newtlaws/mb.cfm and http://www.acs.psu.edu/drussell/demos/superposition/superposition.html]

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The Superposition Principle

If two or more waves combine at a given point, the resulting disturbance is the *sum* of the disturbances of the individual waves.

$$y = y_1 + y_2$$

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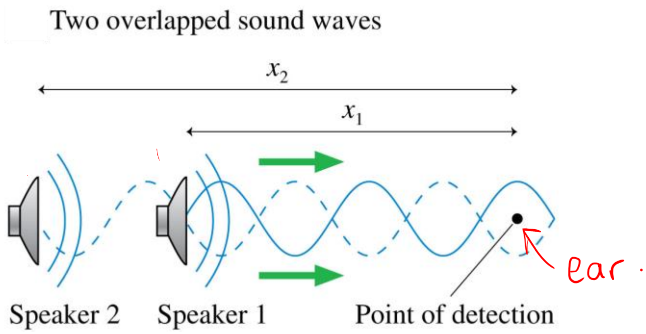
Wave Interference

• The pattern resulting from the superposition of two waves is called interference. Interference can be

• ***constructive***, meaning the disturbances **add** to make a resultant wave of **larger** amplitude, or

• ***destructive***, meaning the disturbances **cancel**, making a resultant wave of **smaller** amplitude.



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Before Class 34 on Monday

- Please read the next three sections of Chapter 11:
- 11.7 Sound Waves, Beats
- 11.8 Standing Waves on Strings
- 11.9 Standing Waves in Air Columns

- There will be three classes next week:
- Monday: Sections 11.7-11.9
- Wednesday: Last Official Class: Section 11.10 on Doppler Effect and course review
- Thursday 11:10am-12:00pm - Wacky Thursday with Bonus TeamUp Quiz / Course Review / Liquid Nitrogen Demonstrations including Levitating Superconductors

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TeamUp Question 3 Further Discussion

$$10^{\log_{10}(x)} = x$$

$$\frac{10^y}{10^x} = 10^{y-x}$$

if sound intensity level increases from $\beta_1 = 50$ dB to $\beta_2 = 80$ dB how does I change.

Solve: $\beta = 10 \log_{10}\left(\frac{I}{I_0}\right)$ for I:

$$\frac{\beta}{10} = \log_{10}\left(I/I_0\right)$$

$$10^{(\beta/10)} = 10^{\log_{10}(I/I_0)} = \frac{I}{I_0}$$

$$I = I_0 10^{\beta/10}$$

$$\frac{I_2}{I_1} = \frac{I_0 10^{\beta_2/10}}{I_0 10^{\beta_1/10}}$$

$$\frac{I_2}{I_1} = 10^{\frac{\beta_2}{10} - \frac{\beta_1}{10}} = 10^{\frac{80}{10} - \frac{50}{10}} \quad 10^{8.5}$$

$$\frac{I_2}{I_1} = 10^3 = 1000$$

$$\frac{I_2}{I_1} = 10^{(\beta_2 - \beta_1)/10}$$

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