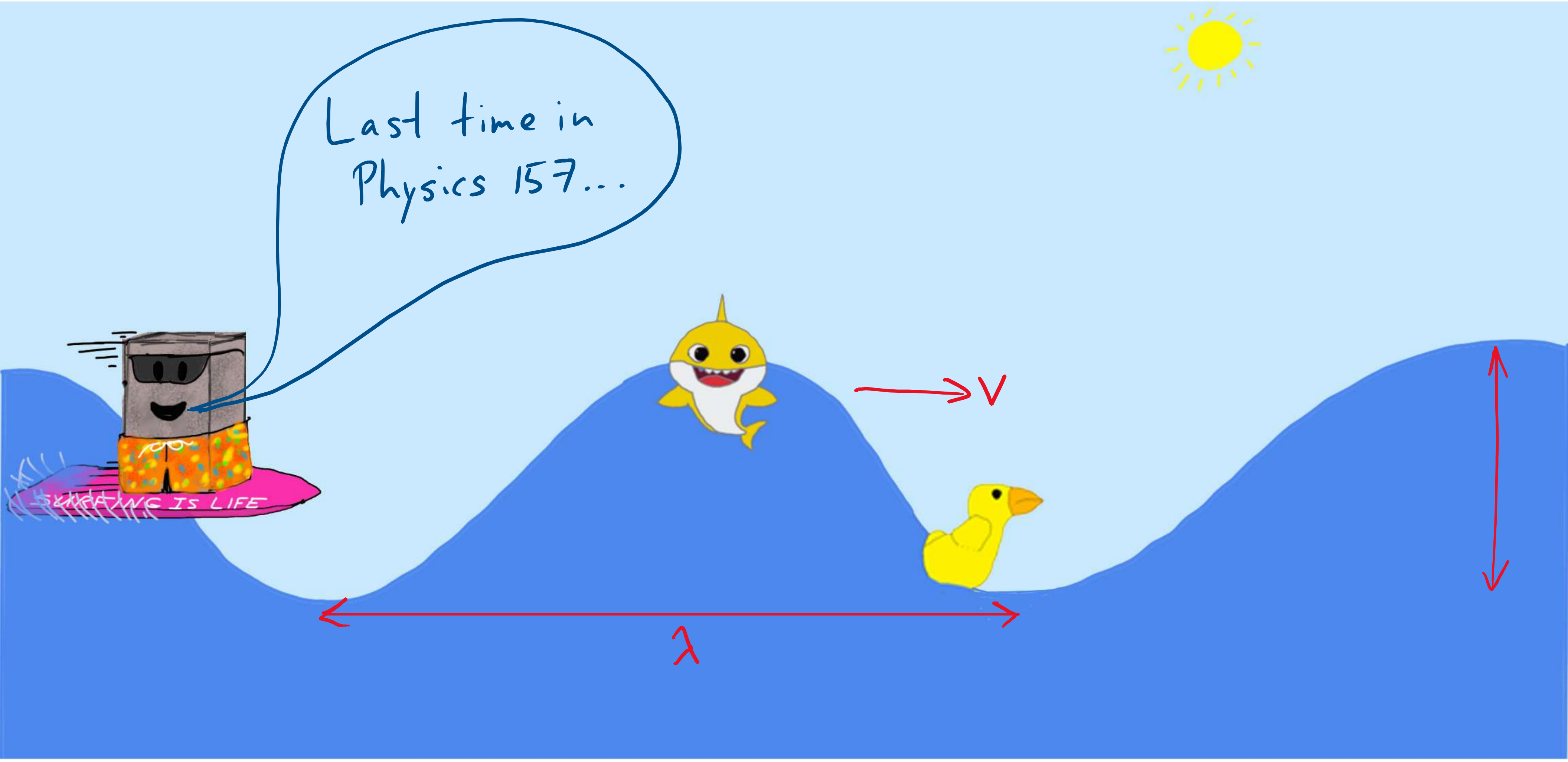
Office hours today: after class (Remo), 4-5pm, 8-9pm (Zoom)

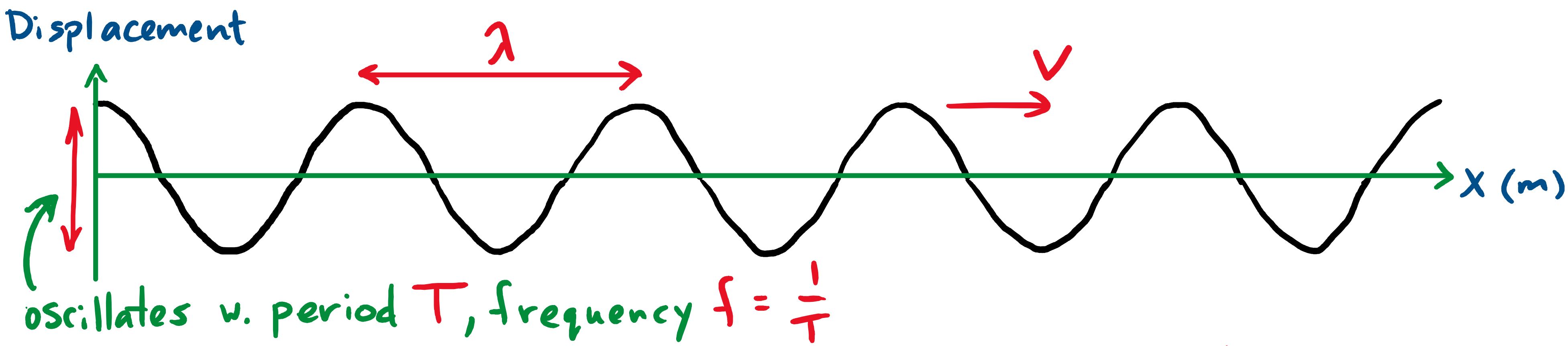
See lecture link page for bonus office hours and video requests

Learning goals for today:

- To use the Superposition to predict the net displacement due to multiple waves travelling on the same medium
- To describe the qualitative properties and precise mathematical description of standing waves and relate these to travelling waves
- To predict the allowed wavelengths and frequencies for standing waves in a situation with fixed or boundaries, such as a guitar string
- To describe which factors contribute to wave speed for waves on a string


Last time in Physics 157...
SURFING IS LIFE
v
λ

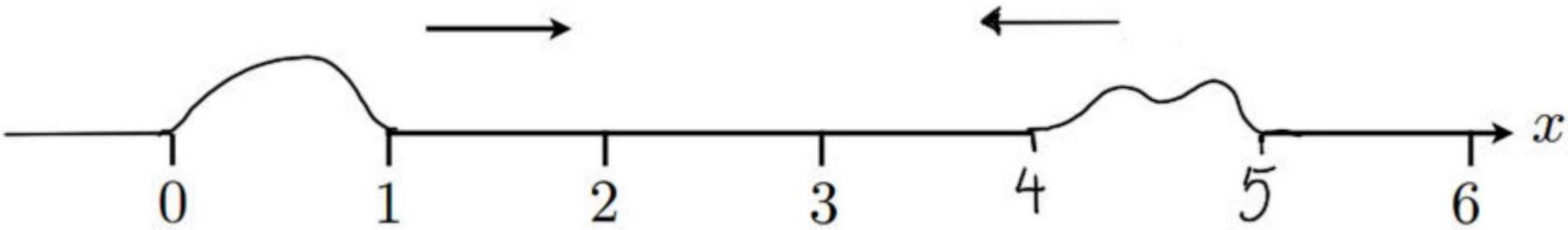
Mathematical Description of Traveling Sinusoidal Waves



Right moving wave: $D(x,t) = A\cos(kx - \omega t)$

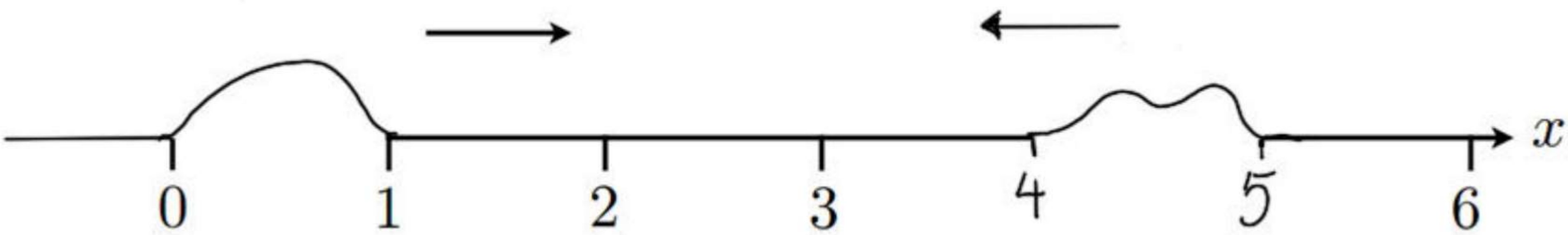
Left moving wave: $D(x,t) = A\cos(kx + \omega t)$

$k = \frac{2\pi}{\lambda}$ $\qquad \omega = \frac{2\pi}{T}$ $\qquad v = \frac{\lambda}{T}$



Two wave pulses are travelling towards each other as shown. When they meet, they will:

A) Bounce off each other and reflect backwards
B) Destroy each other, leaving a few random ripples going in either direction
C) Pass right through each other



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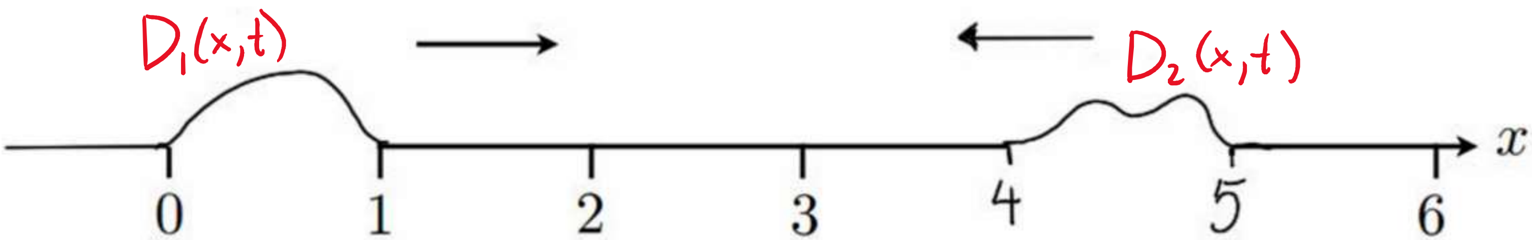
THE PRINCIPLE OF SUPERPOSITION

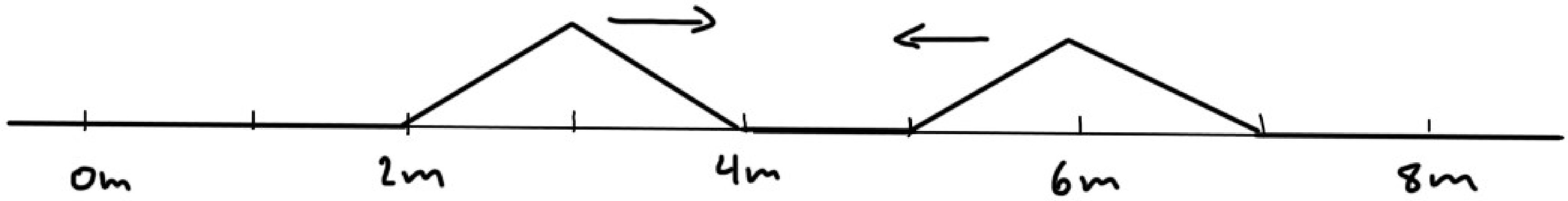
When two or more waves overlap, the net displacement D(x,t) is equal to the sum of the displacements we would have if each wave were present alone.



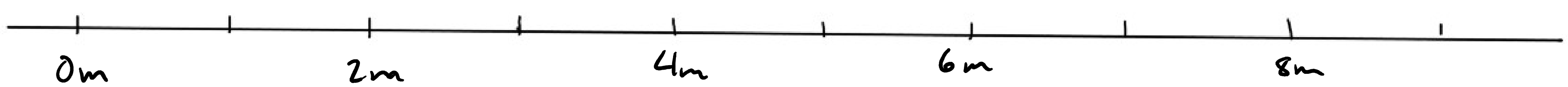
combined wave: $D(x,t) = D_1(x,t) + D_2(x,t)$

★ waves add without disturbing each other ★

Example:



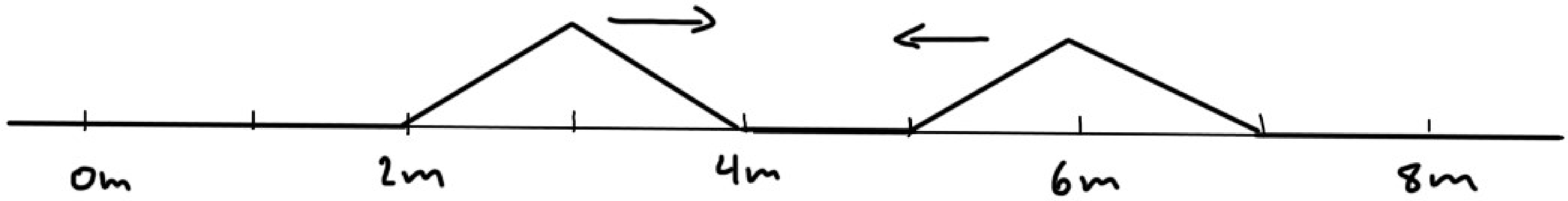
Two wave pulses, each traveling 1m/s, approach each other on a string. Sketch the displacement of the string after 1 second has passed.



Simulation:

https://youtu.be/KAxe05RM_mg

Example:



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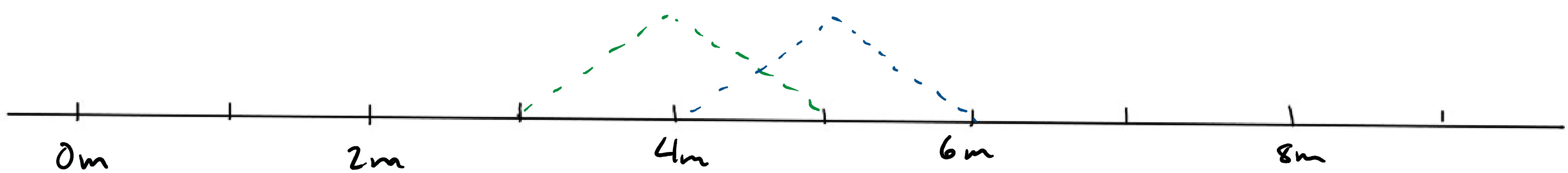

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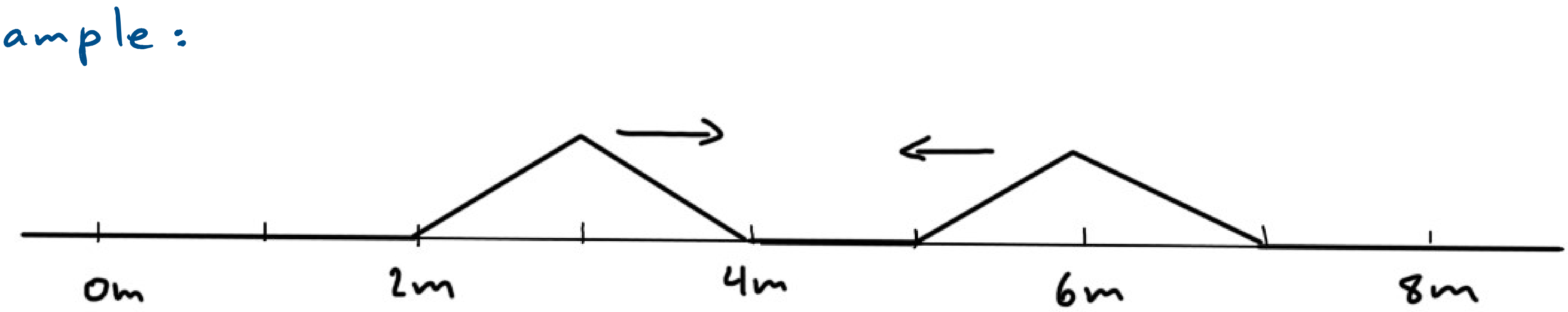

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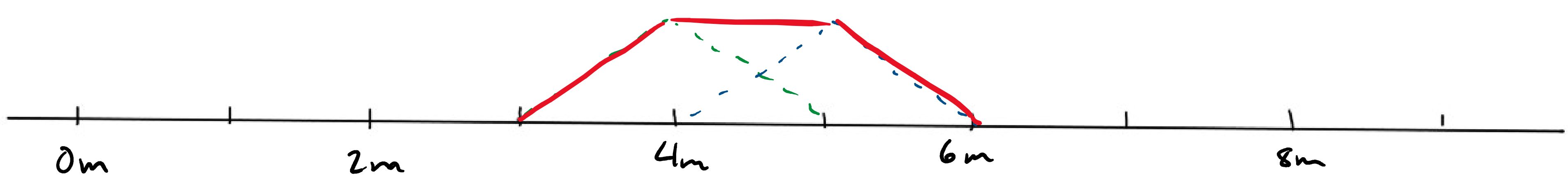
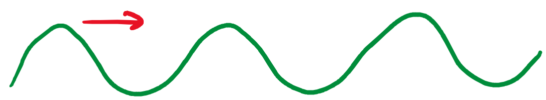
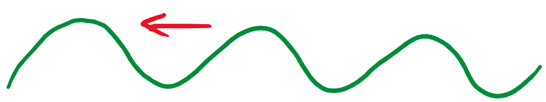


Application: standing waves

Right-moving wave: $A\cos(kx-\omega t)$



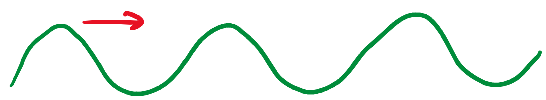
Left-moving wave: $A\cos(kx+\omega t)$



What if both are present on the same string?

Application: standing waves

Right-moving wave: $A\cos(kx-\omega t) = A\cos(kx)\cos(\omega t) + A\sin(kx)\sin(\omega t)$



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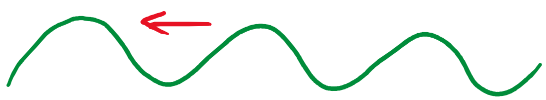
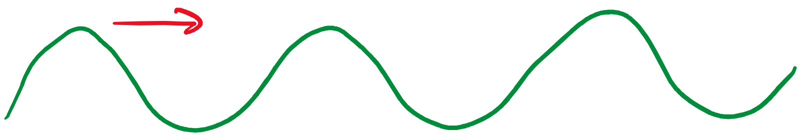


Application: standing waves

Right-moving wave: $A\cos(kx-\omega t) \quad = \quad A\cos(kx)\cos(\omega t) + A\sin(kx)\sin(\omega t)$



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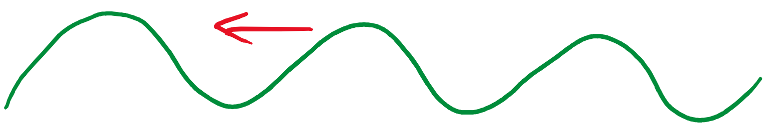
Left-moving wave: $A\cos(kx+\omega t) \quad = \quad A\cos(kx)\cos(\omega t) - A\sin(kx)\sin(\omega t)$



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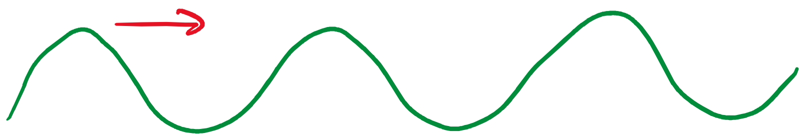

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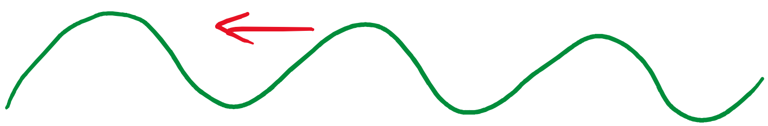

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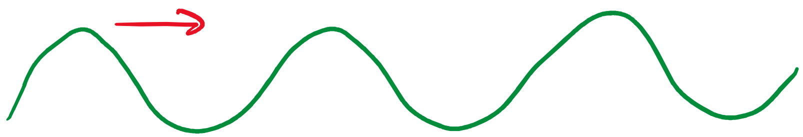
sum: $2A\cos(kx)\cos(\omega t)$

Application: standing waves

Right-moving wave: $A\cos(kx-\omega t) = A\cos(kx)\cos(\omega t) + A\sin(kx)\sin(\omega t)$



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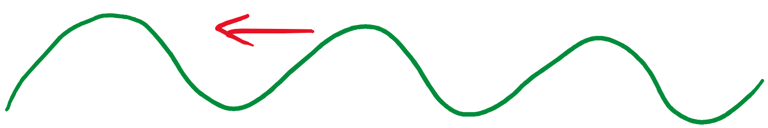

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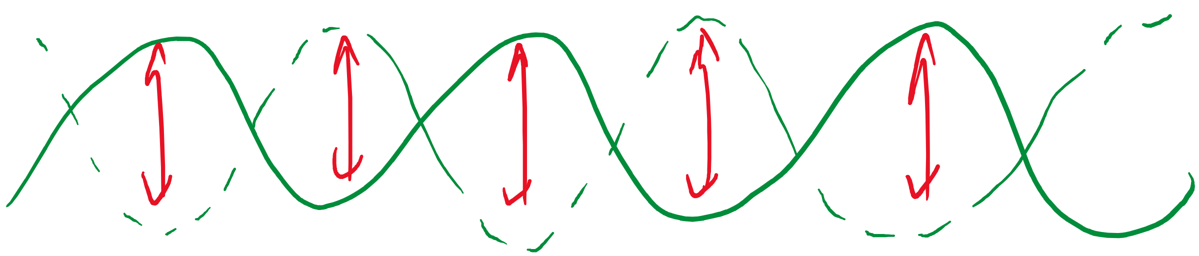
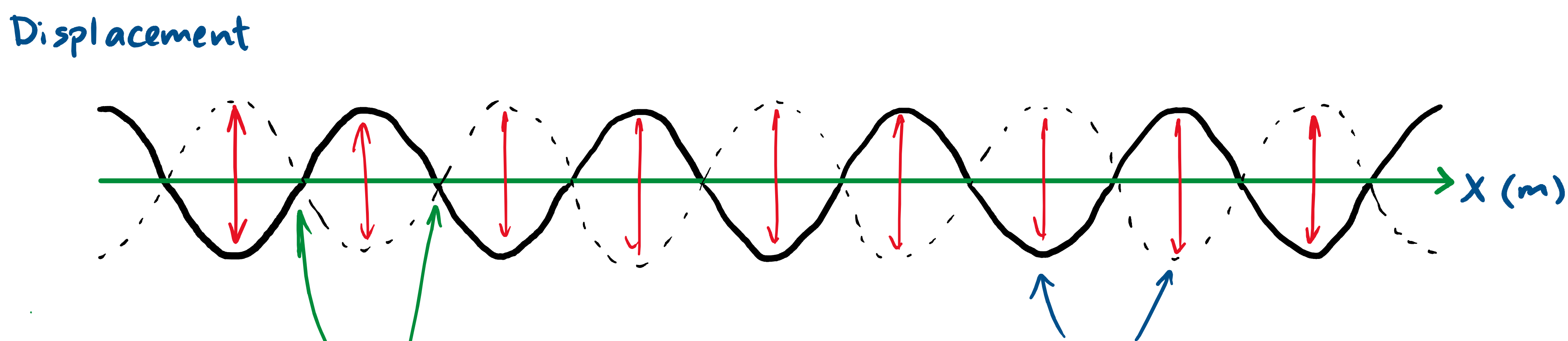


= STANDING WAVE

STANDING WAVES

$$D(x,t) = A\cos(kx)\cdot\cos(\omega t)$$



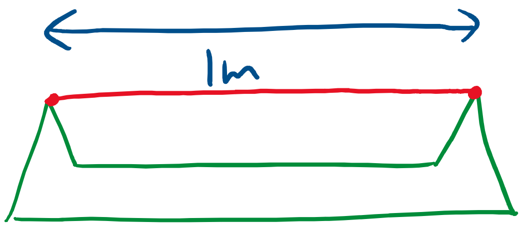
Nodes: displacement fixed at 0

$\cos(kx) = 0$

Antinodes: oscillates w. maximum displacement

$\cos(kx) = \pm 1$

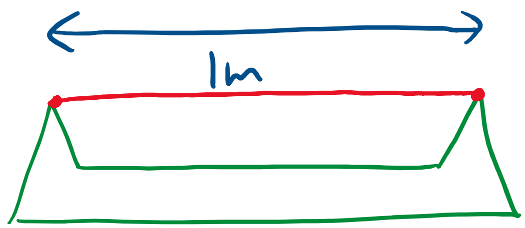
Example: guitar/violin string – displacement must be zero at ends



Q: What are the possible wavelengths for standing waves on a guitar string w. length 1 m?

(Hint: draw the shapes of the possible waves)

Example: guitar/violin string - displacement must be zero at ends



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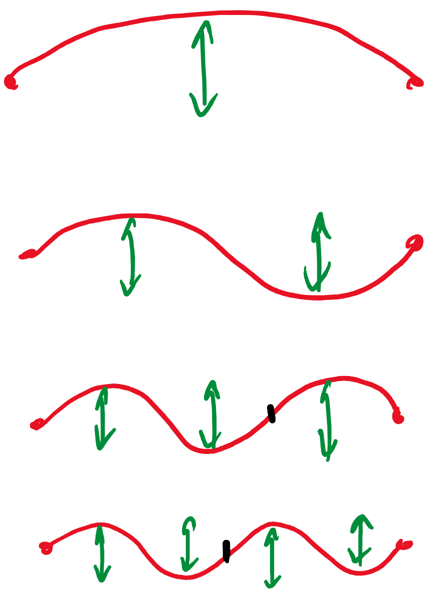


$\lambda = 2m$

$\lambda = 1m$

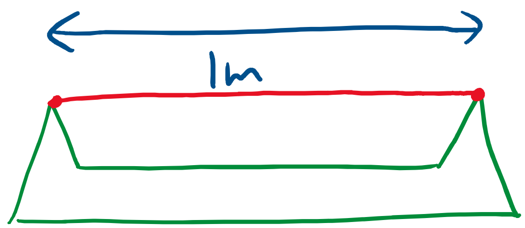
$\lambda = \frac{2}{3}m$

$\lambda = \frac{1}{2}m$

generally: $\lambda = \frac{2m}{n}$

Demo

Example: guitar/violin string – displacement must be zero at ends



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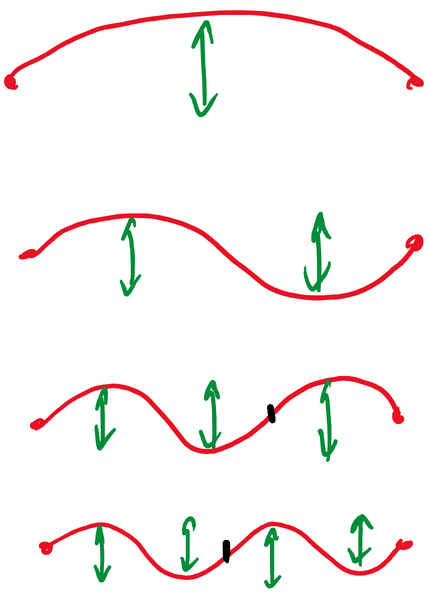

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How do we calculate the frequencies?

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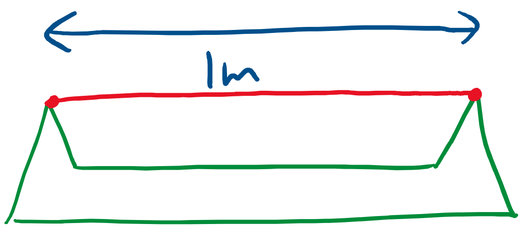

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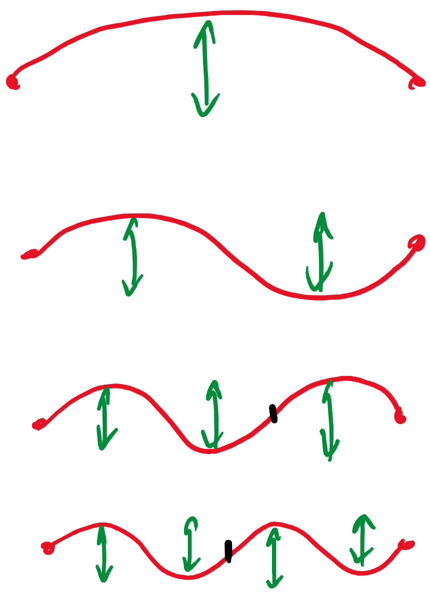

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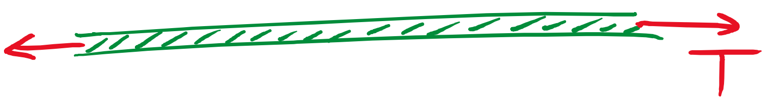
How do we calculate the frequencies?

★ use $f = \frac{v}{\lambda}$ ★

Important: v depends only on properties of our string,
does not depend on λ, f

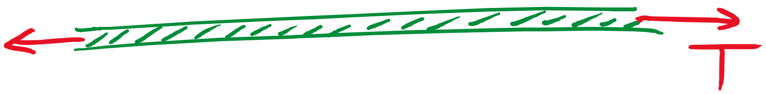


depends on tension T units $N = \frac{kg\,m}{s^2}$

depends on mass/length μ units $\frac{kg}{m}$

Which combination of these has units of velocity?

Important: v depends only on properties of our string, does not depend on λ, f



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Which combination of these has units of velocity?

$v = \sqrt{\frac{T}{\mu}}$ has right units (+ is the right answer!)

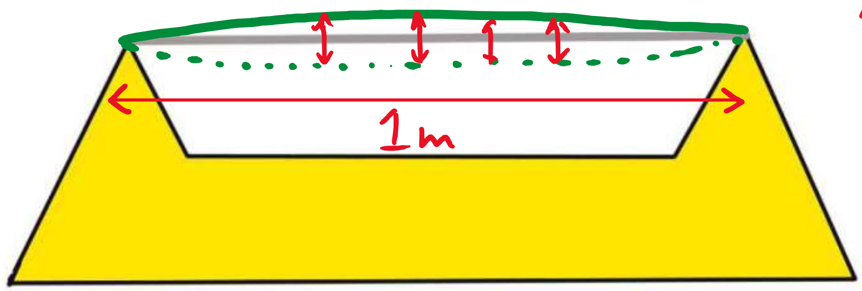
"Dimensional Analysis" detailed derivation in 15.4

Example: Which note started the Very Serious Skipping+Clapping Race

wire diameter: 1mm $T = 800N$

density of platinum: $2.14 \times 10^4 kg/m^3$

Question 1:



You are the Grand Engineer for the Island Nation of Bthththx (pronounced as written). Each year, on the last day of summer, a new Knightship of Bthththx is awarded to the winner of the Very Serious Skipping and Clapping Race, in which participants (18 years of age and older) must skip and clap through a full lap around the island's perimeter, adhering to the rather strict regulations of the National Skipping and Clapping Federation.

The race begins when the Venerable Leader of Bthththx plucks a single note on the Most Perfect Plucking Instrument, which consists of a single 1mm thick platinum wire stretched between two points on a solid gold frame, as shown in the picture. To achieve the proper note, the wire must be at a tension of 800N. On the morning of the race, you notice the temperature