Physics 1240: Sound and Music

Today (7/29/19): Percussion: Vibrating Beams
*HW 3 due at the front, HW 4 now posted (due next Mon.)

Next time: Percussion: Vibrating Membranes

Review

Types of Instruments
(Hornbostel–Sachs classification)

- Chordophones: vibrating strings

- Aerophones: vibrating columns of air

- Idiophones: vibrating the whole instrument

- Membranophones: vibrating membrane/skin

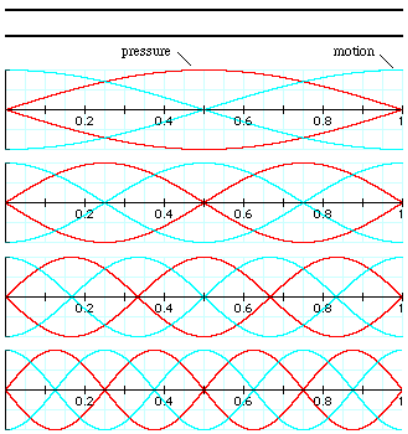
- Electrophones: vibrating loudspeaker

Review

Aerophones

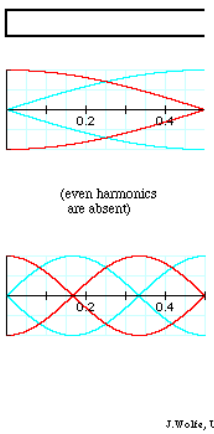
- Free
  (no standing waves)
- Flute-type
  (edge tones)
- Reed-type
  (vibrating reed/lips)

e.g. flute, recorder



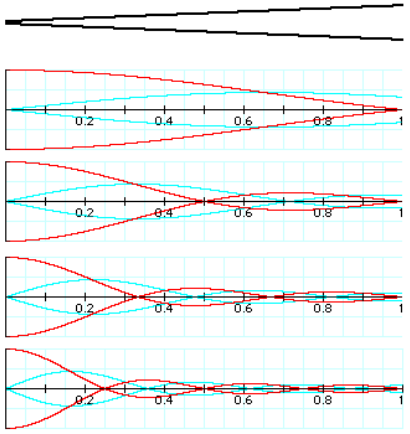
$$f_n = n\frac{v}{2L}$$

e.g. clarinet



$$f_n = n\frac{v}{4L}$$

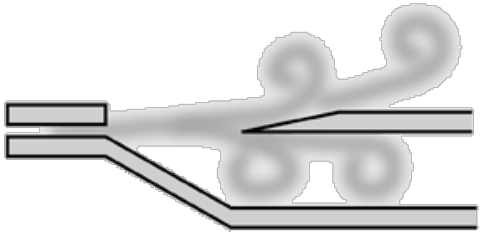
e.g. saxophone, oboe, bassoon



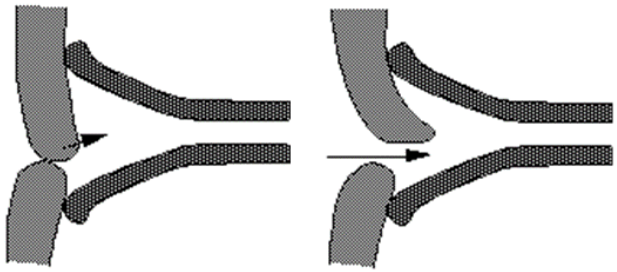
$$f_n = nf_1$$

- How to create waves:

Edge tones



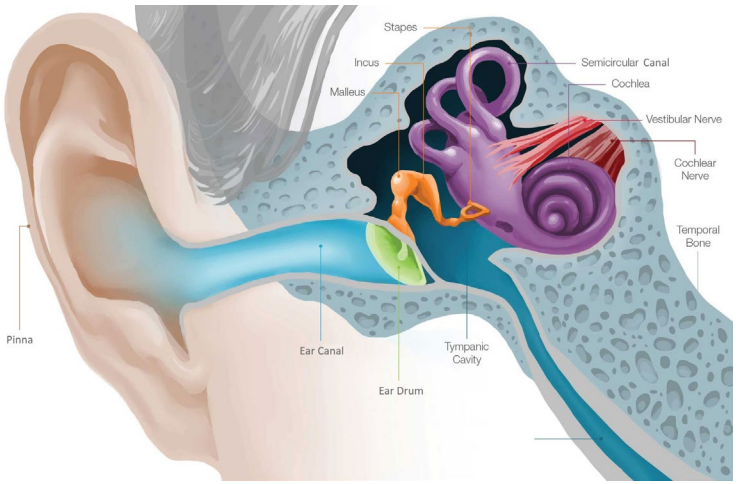
Bernoulli effect

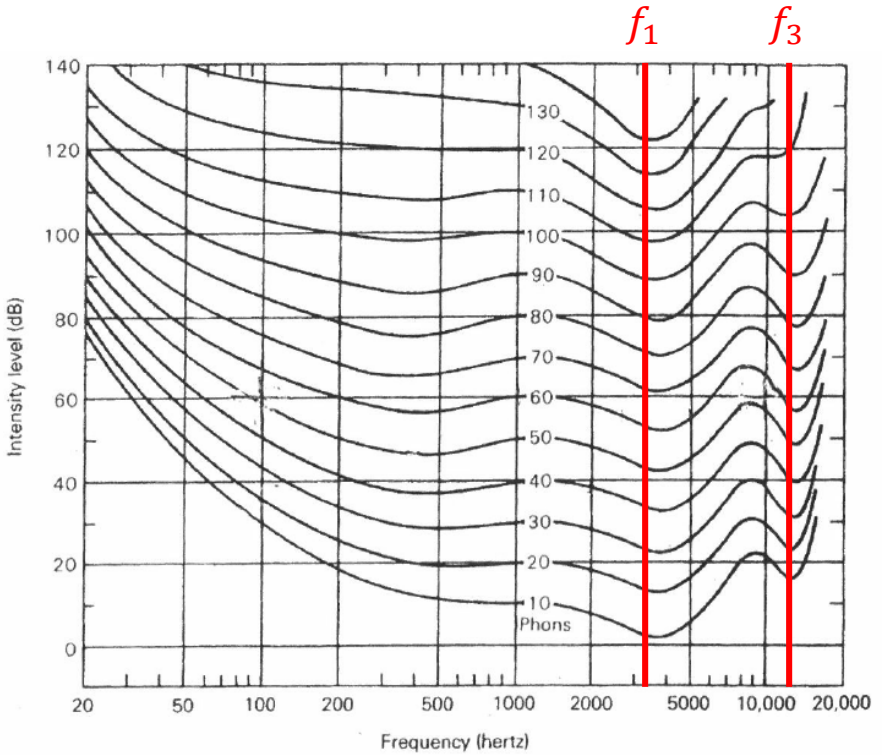


Review

- Tone holes, valves: decrease/increase effective length *L*
- Register holes, octave holes: excite 3rd/2nd harmonics

- Ear canal: tube closed at one end





Clicker Question 14.1

A 1 m long, homemade PVC pipe flute has a large, open tone hole that is a distance 0.6 m from the source end of the flute. What frequencies are present in the spectrum (in Hz)?

A) 286, 572, 857, …
B) 143, 286, 429, …
C) 143, 429, 715, …
D) 286, 857, 1429, …
E) 172, 343, 515, …

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D) 286, 857, 1429, …
E) 172, 343, 515, …

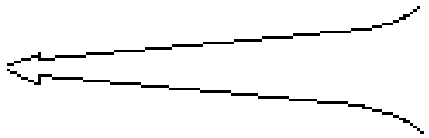
- Flute: open-open tube
- Tone hole: decreases L from 1 m to 0.6 m

$$f_n = n\frac{v}{2L} = n\frac{343\ \text{m/s}}{2(0.6\ \text{m})}$$
$$= n(286\ \text{Hz})$$

Clicker Question 14.2

An oboe can be modelled as a cone open at one end. If a note on the oboe has a fundamental frequency of 120 Hz, what is the approximate frequency of the next highest mode of vibration?

A) <240 Hz
B) 240 Hz
C) 360 Hz
D) >360 Hz



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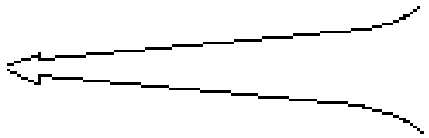
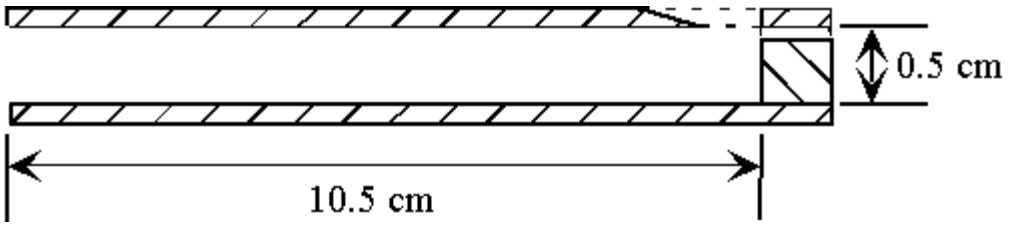


Cone's spectrum has harmonic frequencies $f, 2f, 3f, \ldots$

Clicker Question 14.3

You have built a wooden whistle as shown in the diagram below, with an open end on the left and a small opening off to the side on the right. The question is asked of whether the instrument is better modeled as an open-open tube or a closed-open tube. If you measure a fundamental frequency of about 1500 Hz. Which is it?

A) Open-open tube
B) Closed-open tube



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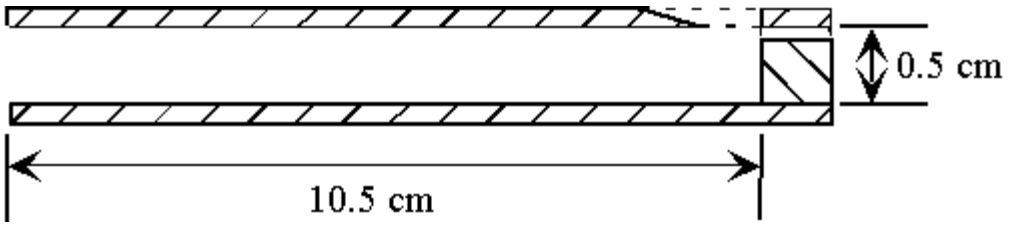
A) Open-open tube
B) Closed-open tube

$$f_1 = \frac{v}{2L} = \frac{343\ \text{m/s}}{2(0.105\ \text{m})} = 1633\ \text{Hz}$$

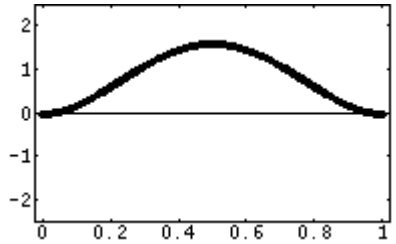


Natural Modes of Vibration

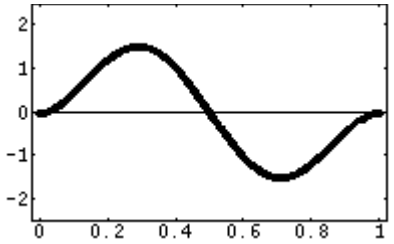
- Natural Mode: the pattern of a particular vibration of an object that can bend and spring back
- Fundamental mode: the vibrational pattern for the lowest frequency at which an object can vibrate
- Partial: the frequency at which a particular natural mode vibrates
- Harmonic: a particular partial that is an integer multiple of the fundamental frequency

Vibrating Beams

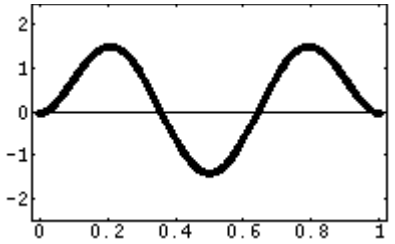
1st mode



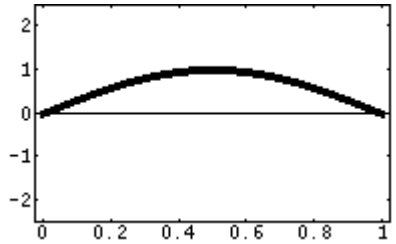
2nd mode

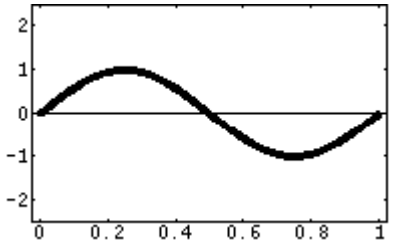


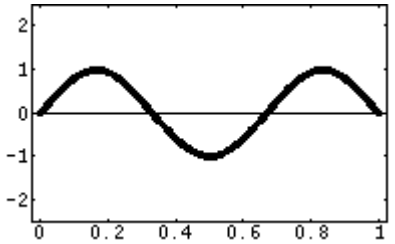
3rd mode



Fixed support ("clamp") at both ends





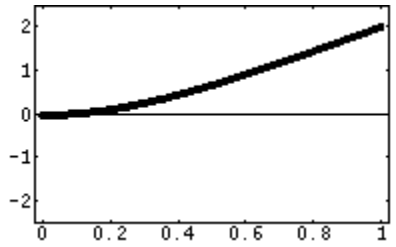


Simple support ("pin") at both ends

Vibrating Beams

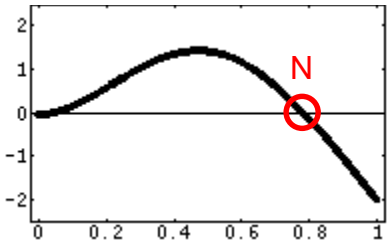
- Clamped-free beam:

1st mode



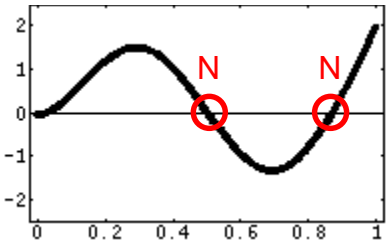
$$f_1 \propto \frac{d^2}{L^2}\sqrt{\frac{k}{m}}$$

2nd mode



$$f_2 \approx 6.267 f_1$$

3rd mode



$$f_3 \approx 17.551 f_1$$

(Euler-Bernoulli theory)

BA

Clicker Question 14.4

If an ideal clamped-free beam is plucked from its end, what will it sound like (assuming none of the modes decay too quickly)?

A) Pure tone with a single frequency
B) Rich tone with multiple frequencies
C) No distinct tone (noise)

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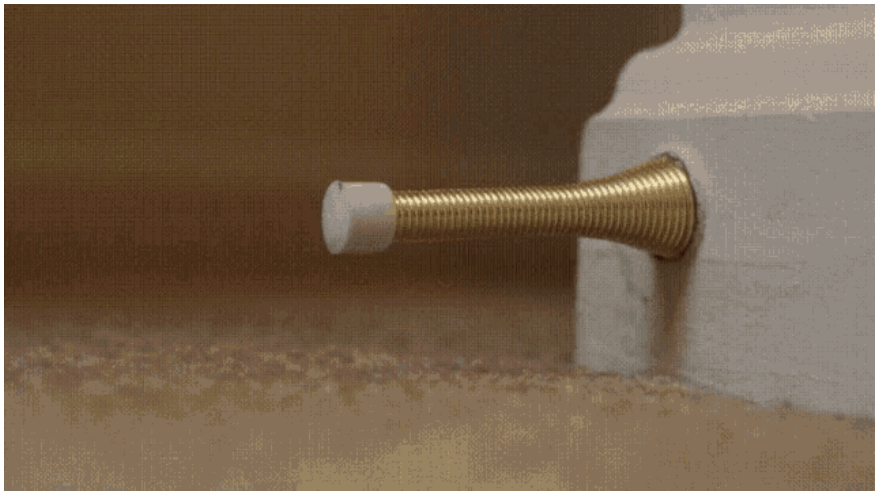
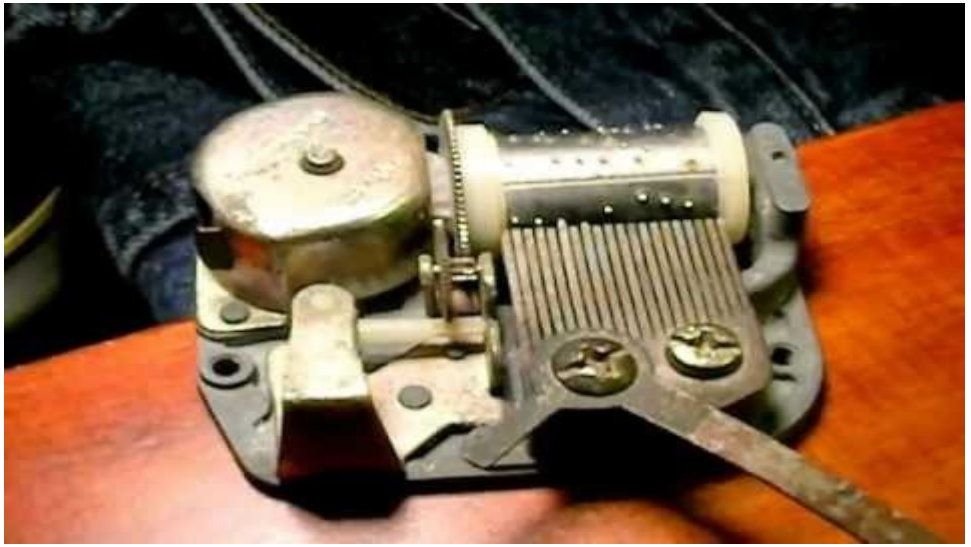


Vibrating Beams

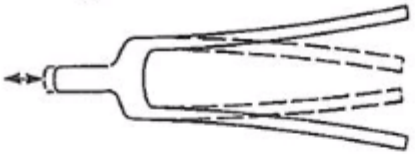
- Clamped-free beam (examples)
  - Jaw harp
  - Music box
  - Thumb piano
  - Tuning fork



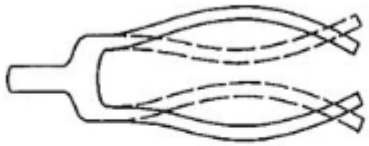
Vibrating Beams

- Clamped-free beam: tuning fork

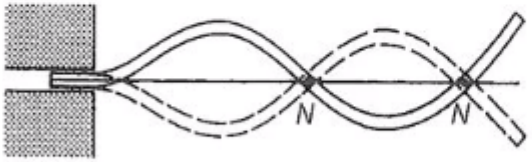
Fundamental mode:

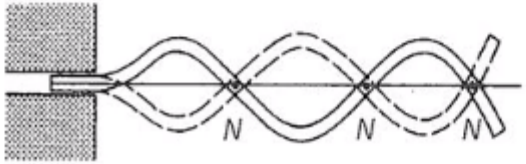


Clang mode:



- What determines the sound we hear?
  - Which modes are sounded
  - How quickly modes decay

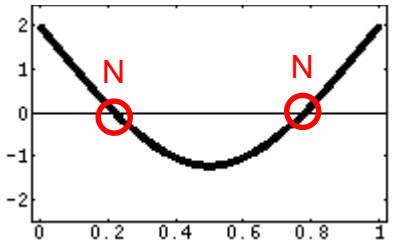




Vibrating Beams

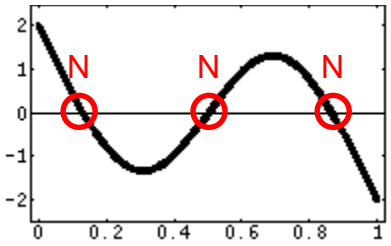
- Free-free beam:

1st mode



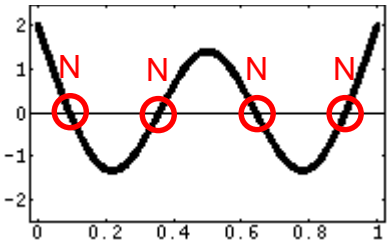
$$f_1 \propto \frac{d^2}{L^2}\sqrt{\frac{k}{m}}$$

2nd mode



$$f_2 \approx 2.757 f_1$$

3rd mode



$$f_3 \approx 5.404 f_1$$

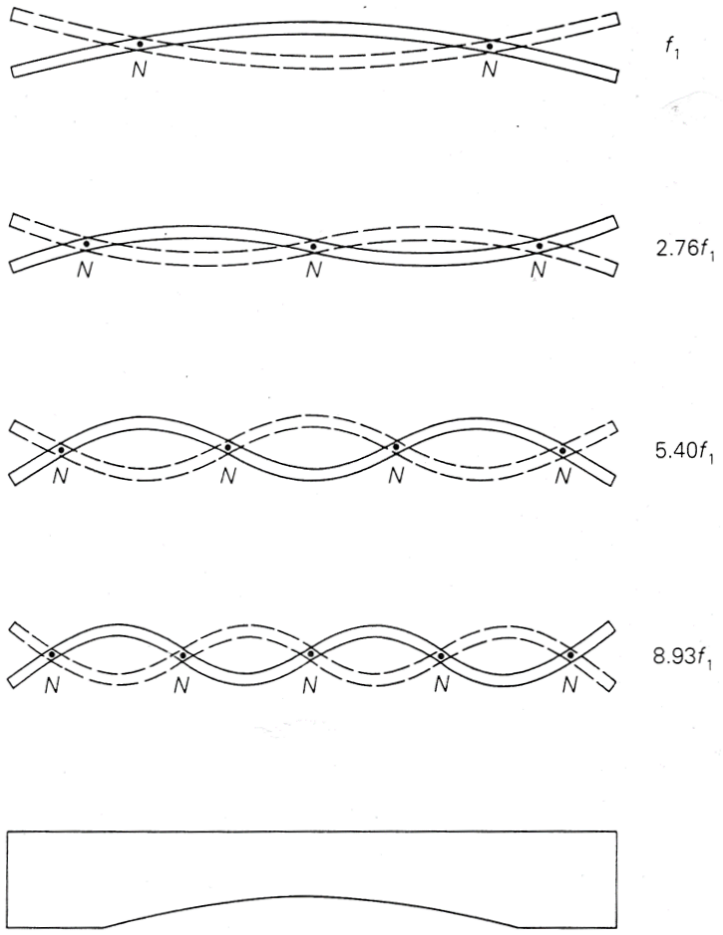
(Euler-Bernoulli theory)

Vibrating Beams

- Free-free beam (examples)
  - Celeste
  - Claves
  - Wind Chimes
  - Triangle
  - Xylophone
  - Marimba

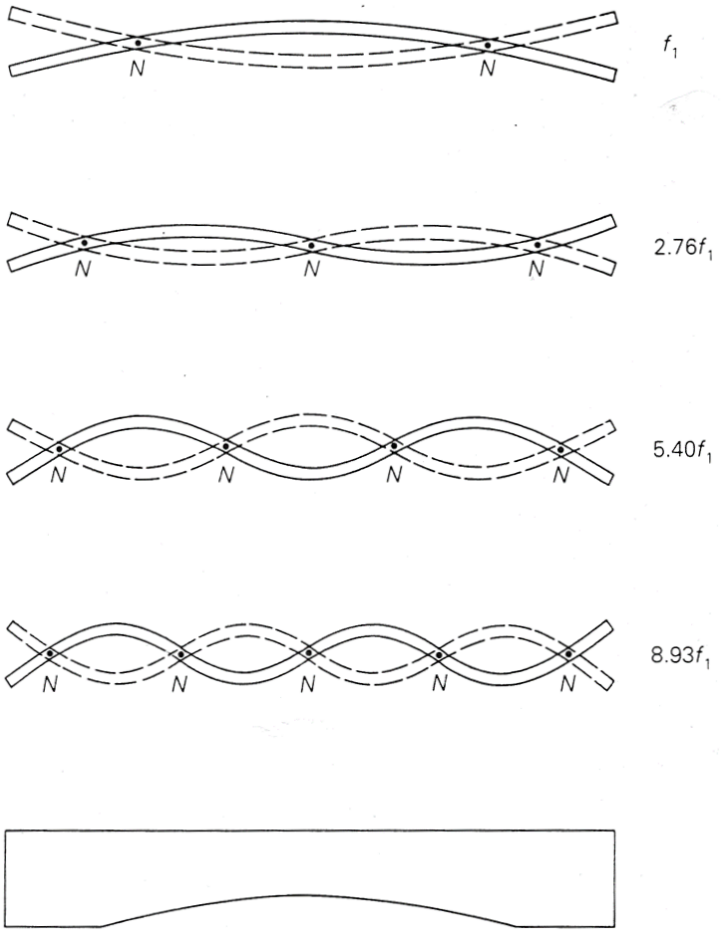
Vibrating Beams

- **Free-free beam**: xylophone ($f_1, 3f_1, \ldots$), marimba ($f_1, 4f_1, \ldots$)



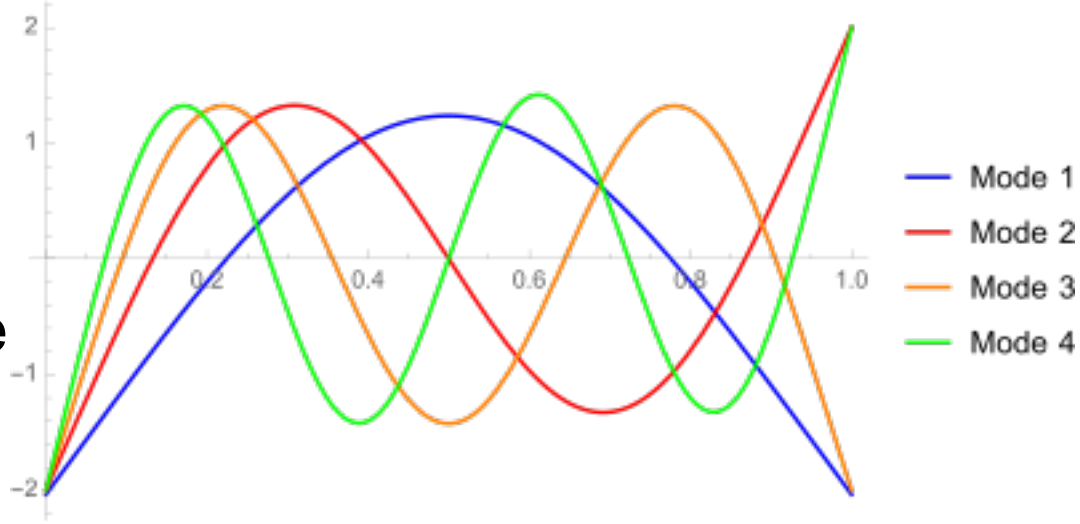
Vibrating Beams

- How to determine which modes are sounded?
  - Striking an object at any given point will sound each natural mode in proportion to how much that mode involves motion of that point
  - Fixing an object to any given point will sound each natural mode that has a node at that point



BA

Clicker Question 14.5

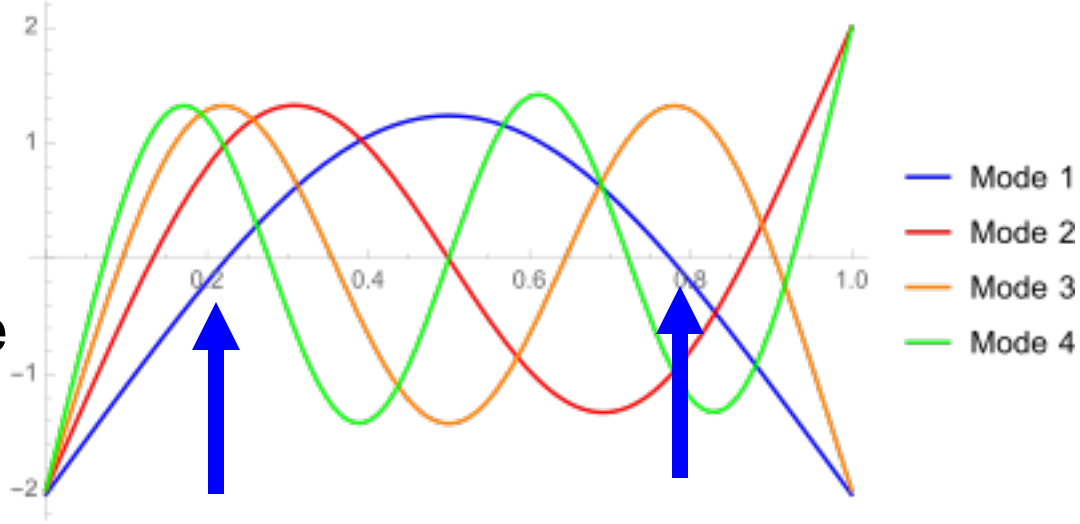


The bars of a xylophone sit on top of supports made of a soft material. Where should these supports be placed to most effectively sound the fundamental mode?

A) One at each extreme end
B) One in the middle
C) One 10% of the way from each end
D) One 20% of the way from each end
E) One 30% of the way from each end

BA

Clicker Question 14.5



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Tutorial 8

Find a group of 3 or 4 to work with for the rest of the class time