DIGITAL SPEECH

YU/HUGHES

SEPTEMBER 9, 2021

UMASS AMHERST

TIME TO WORK ON REVIEW QUESTIONS

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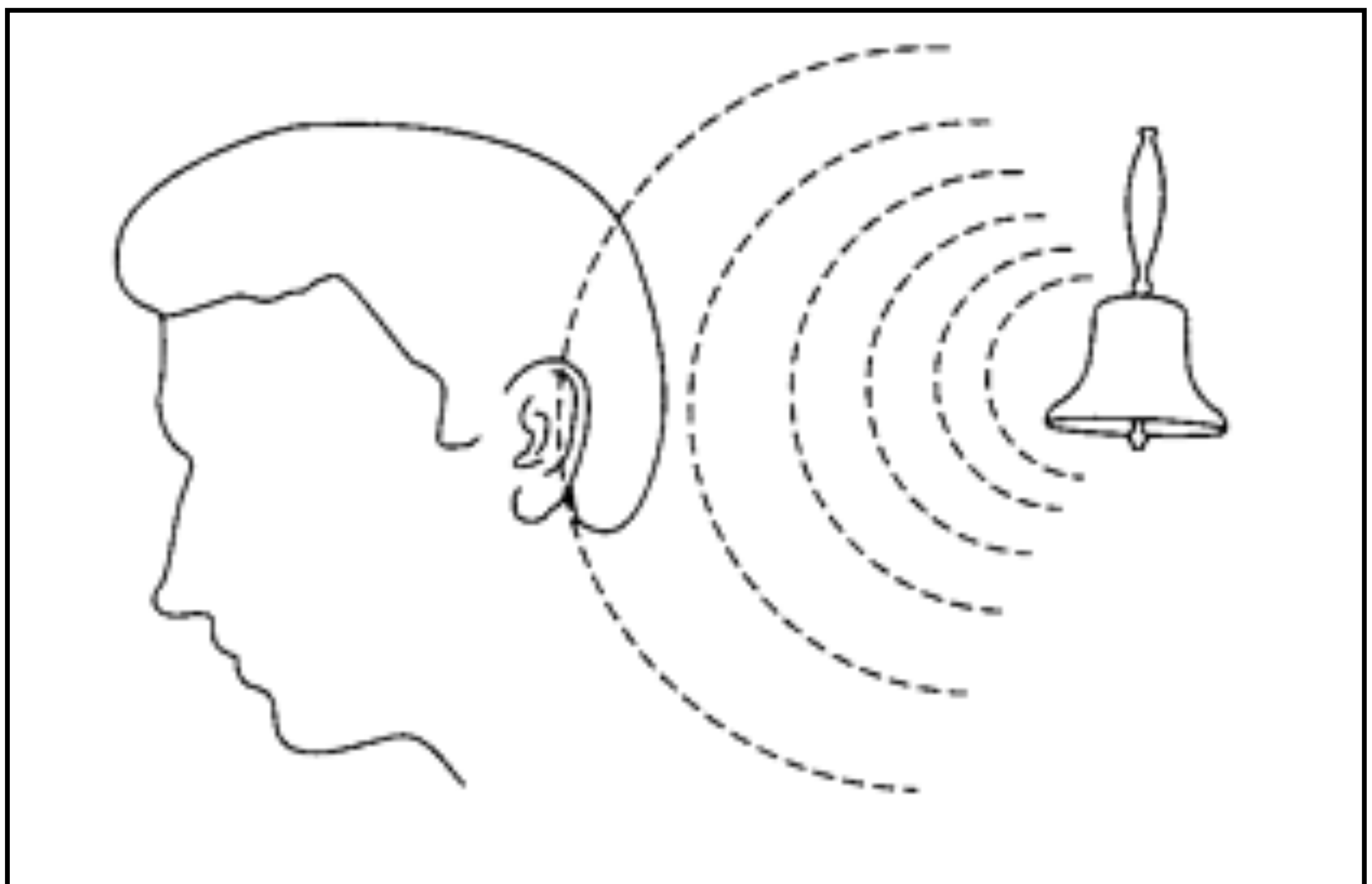
Follow up on this for HW!

SOUND AND DIGITAL SPEECH REVIEW

WHAT IS SOUND?

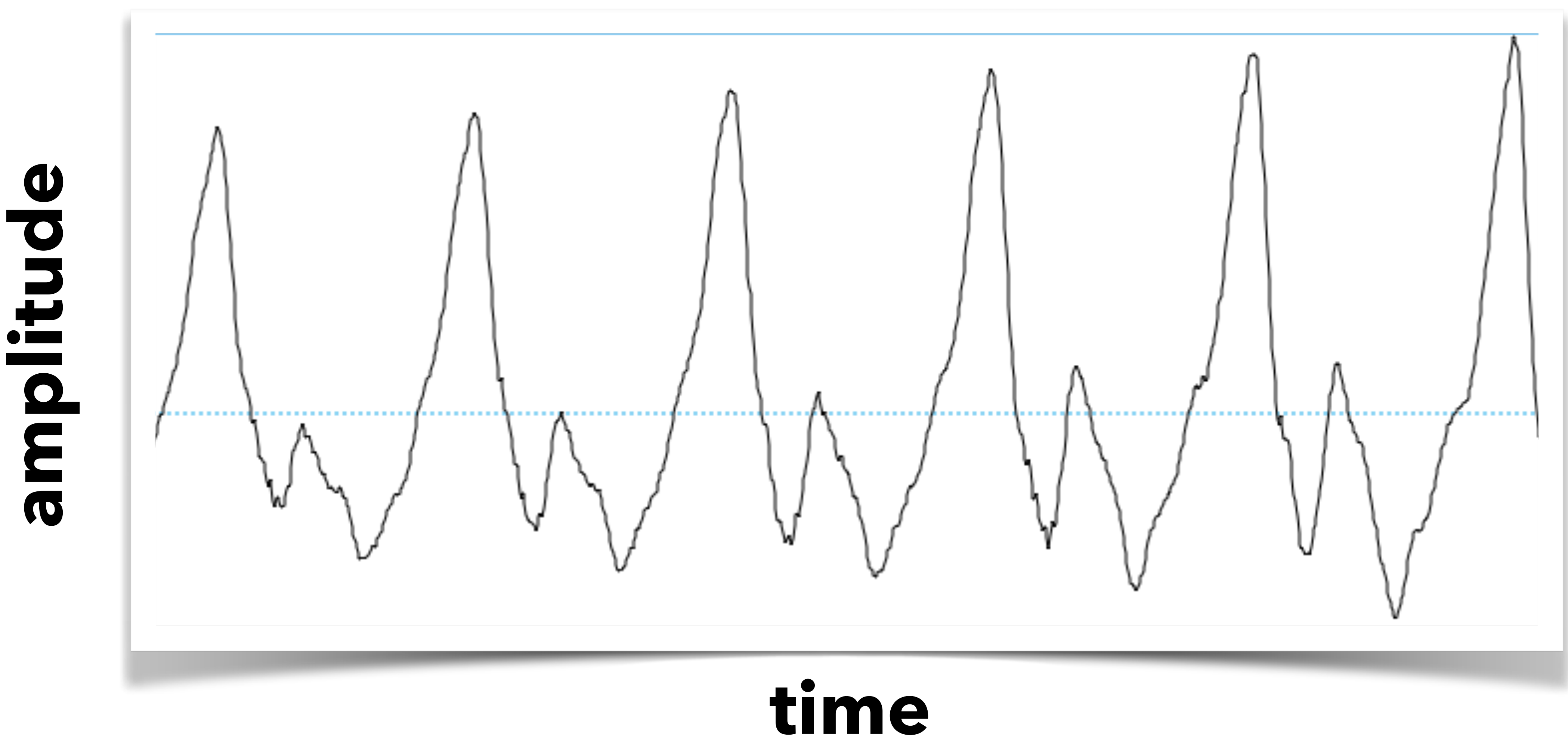
Sound is the sensation you experience when your auditory nerves are stimulated by vibrating air molecules.



clapper >
sides of bell >
adjacent air molecules >
further air >
eardrum

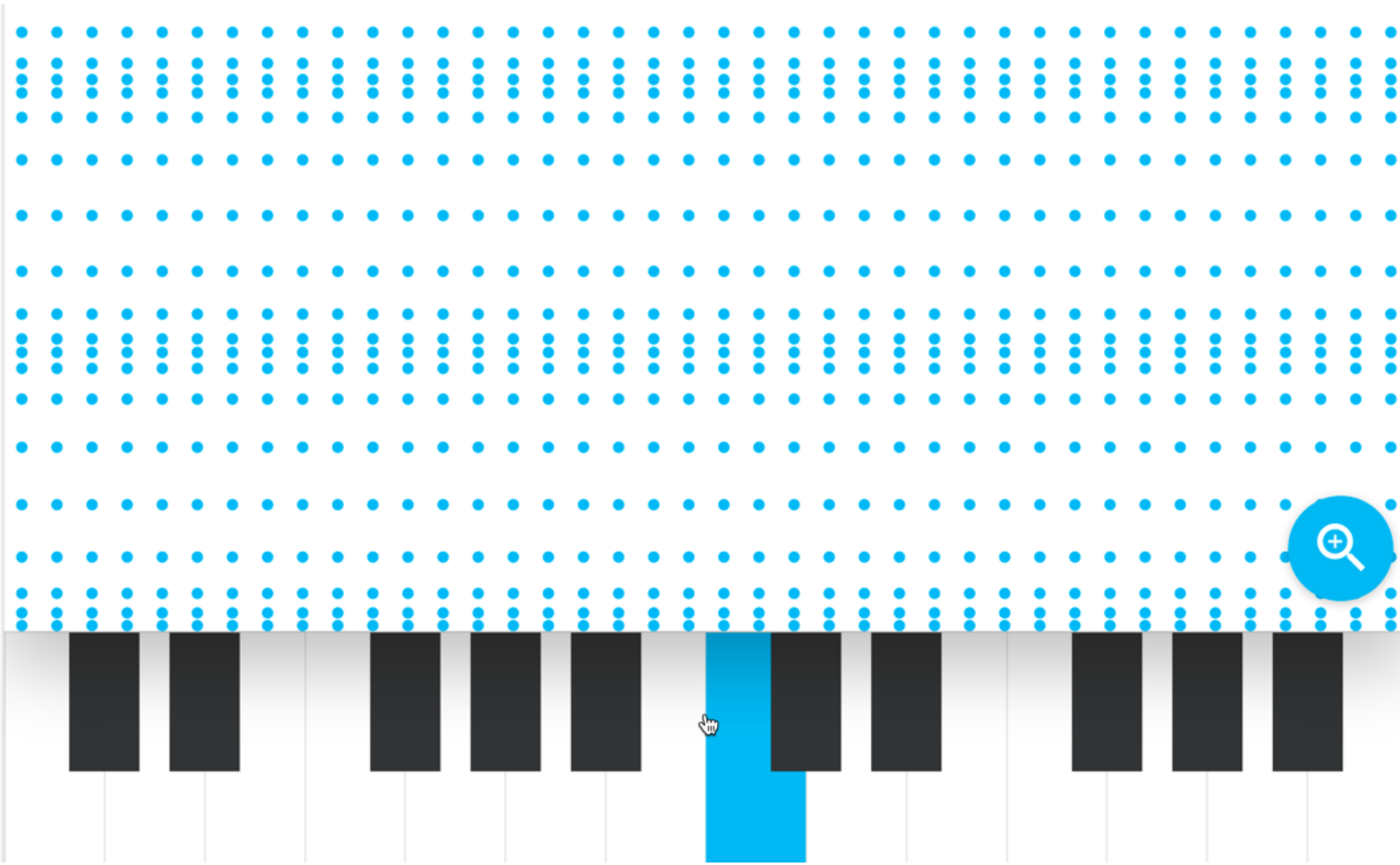
WHAT ARE SOUND WAVES?

Sound waves are pressure variations over time in the air transmitted by the movements of air molecules.

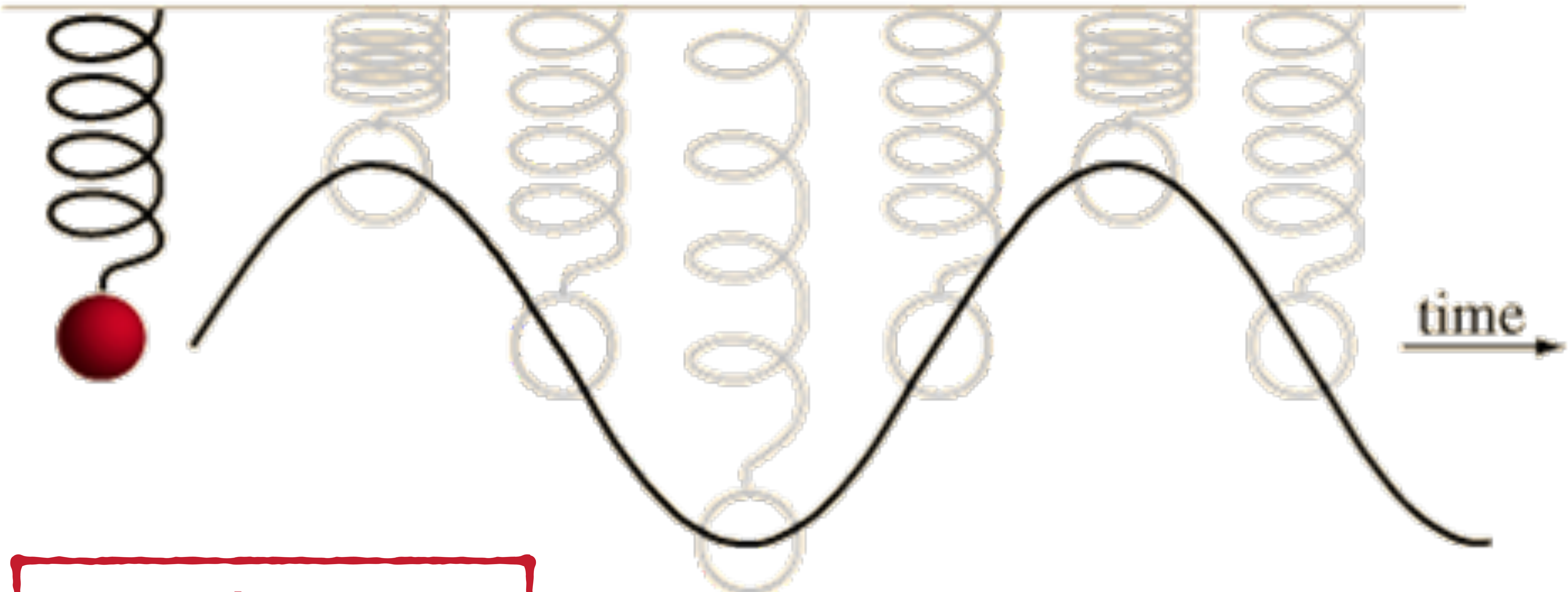


SOUND WAVES HANDS-ON

https://musiclab.chromeexperiments.com/Sound-Waves



SINE WAVES: SIMPLE HARMONIC MOTION



Period *T*

Amplitude *A*

Frequency *f*

http://www.gailruby.com/SHMGraph.htm

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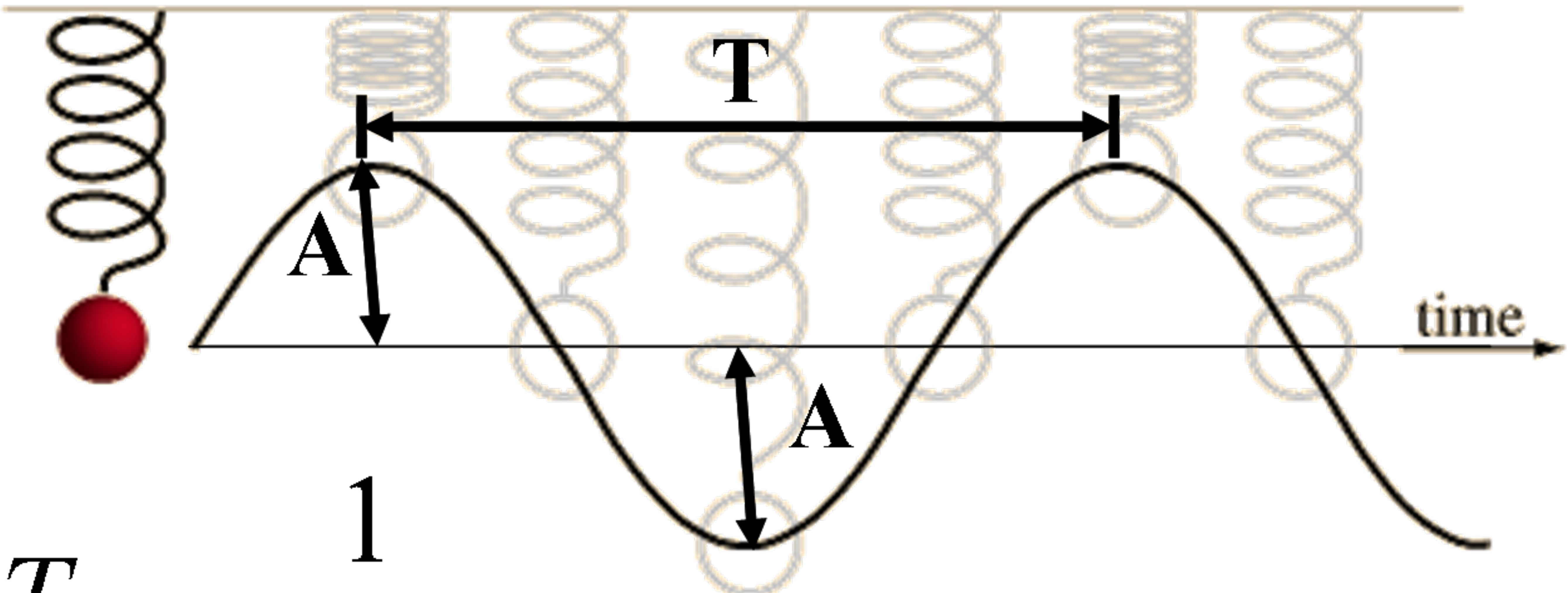
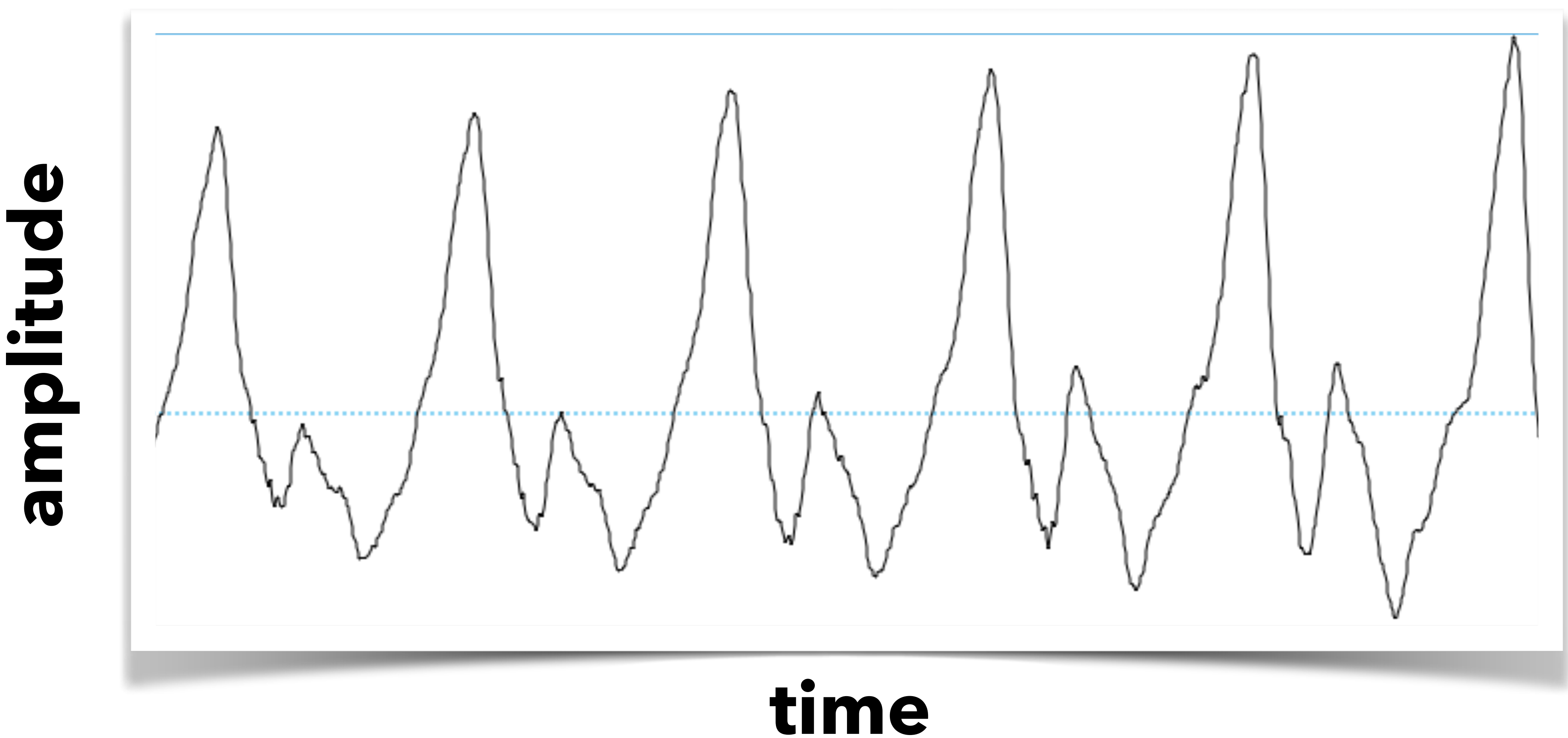


$$T = \frac{1}{f}$$

http://www.gailruby.com/SHMGraphwithrelations.htm

IT'S AN ANALOG WORLD

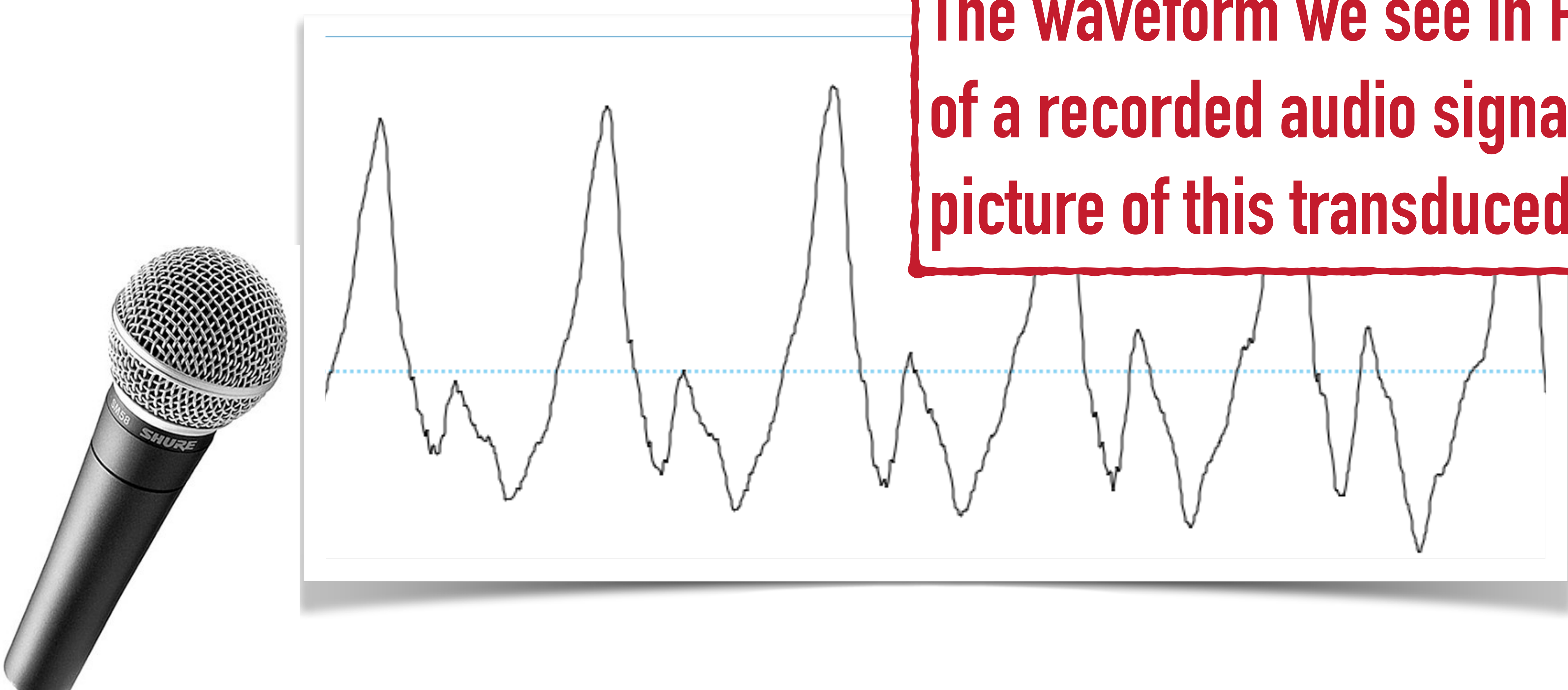
These pressure variations are continuous in both dimensions ("analog").



THE WAVEFORM

- A microphone picks up the air pressure waves, like an eardrum, but then **transduces** the sound energy from air pressure into an electrical voltage.

The waveform we see in Praat of a recorded audio signal is a picture of this transduced wave



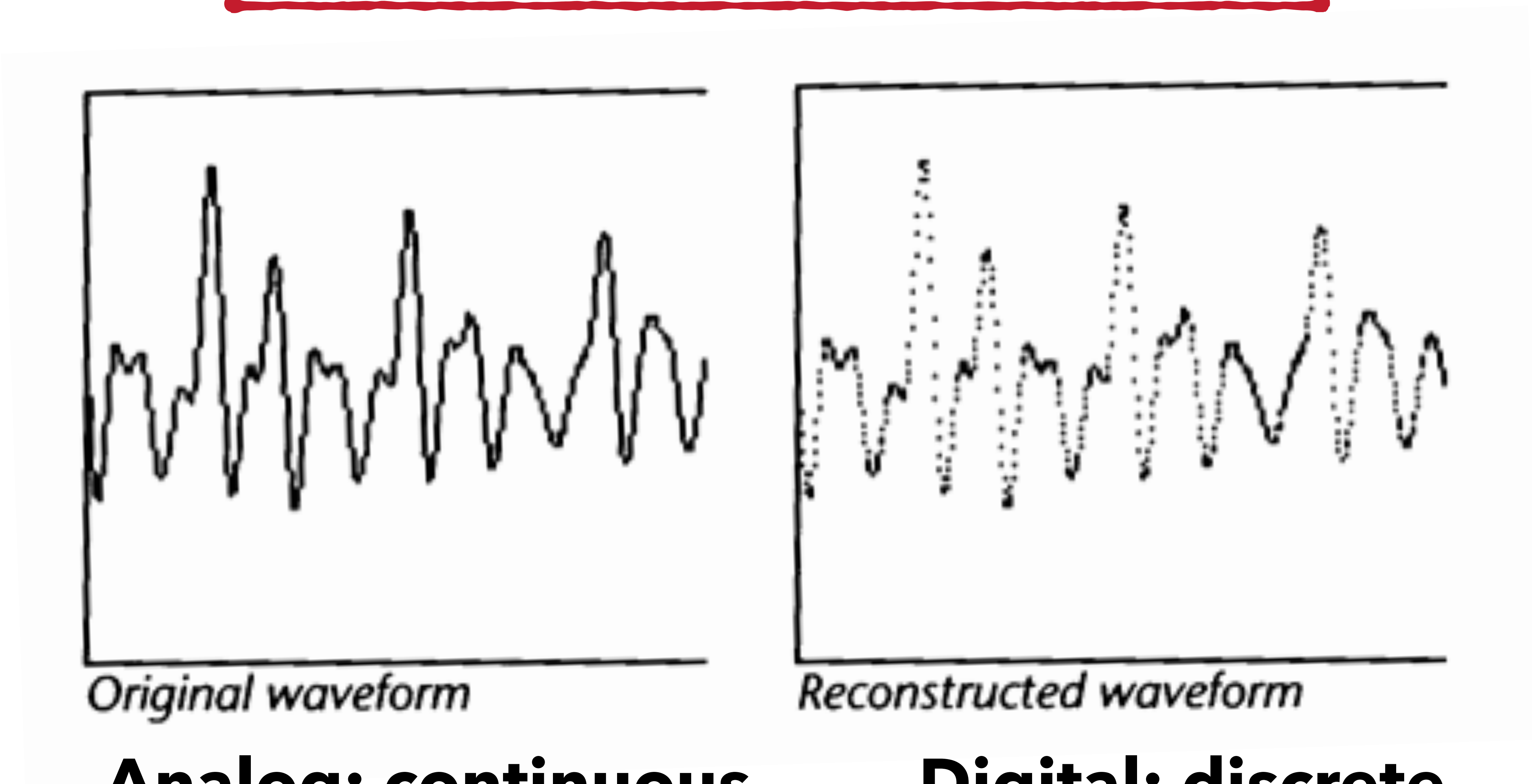
IT'S A DIGITAL WORLD

- But computers store information digitally as 1s and 0s!
- So how do we get between an analog signal and a digital signal?

ANALOG ⇄ DIGITAL

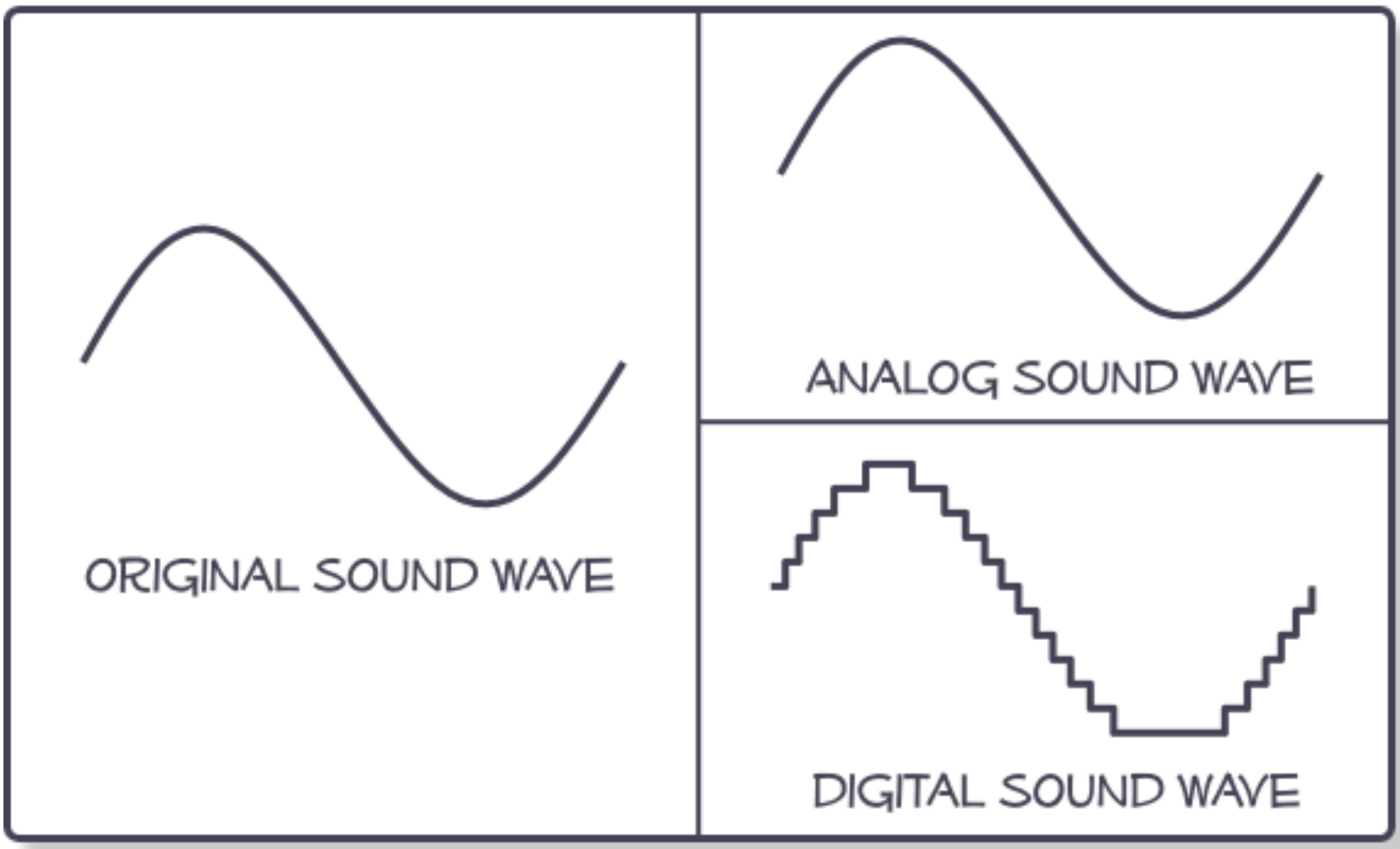
Analog-to-digital conversion (A/D) →

Digital-to-analog conversion (D/A) ←



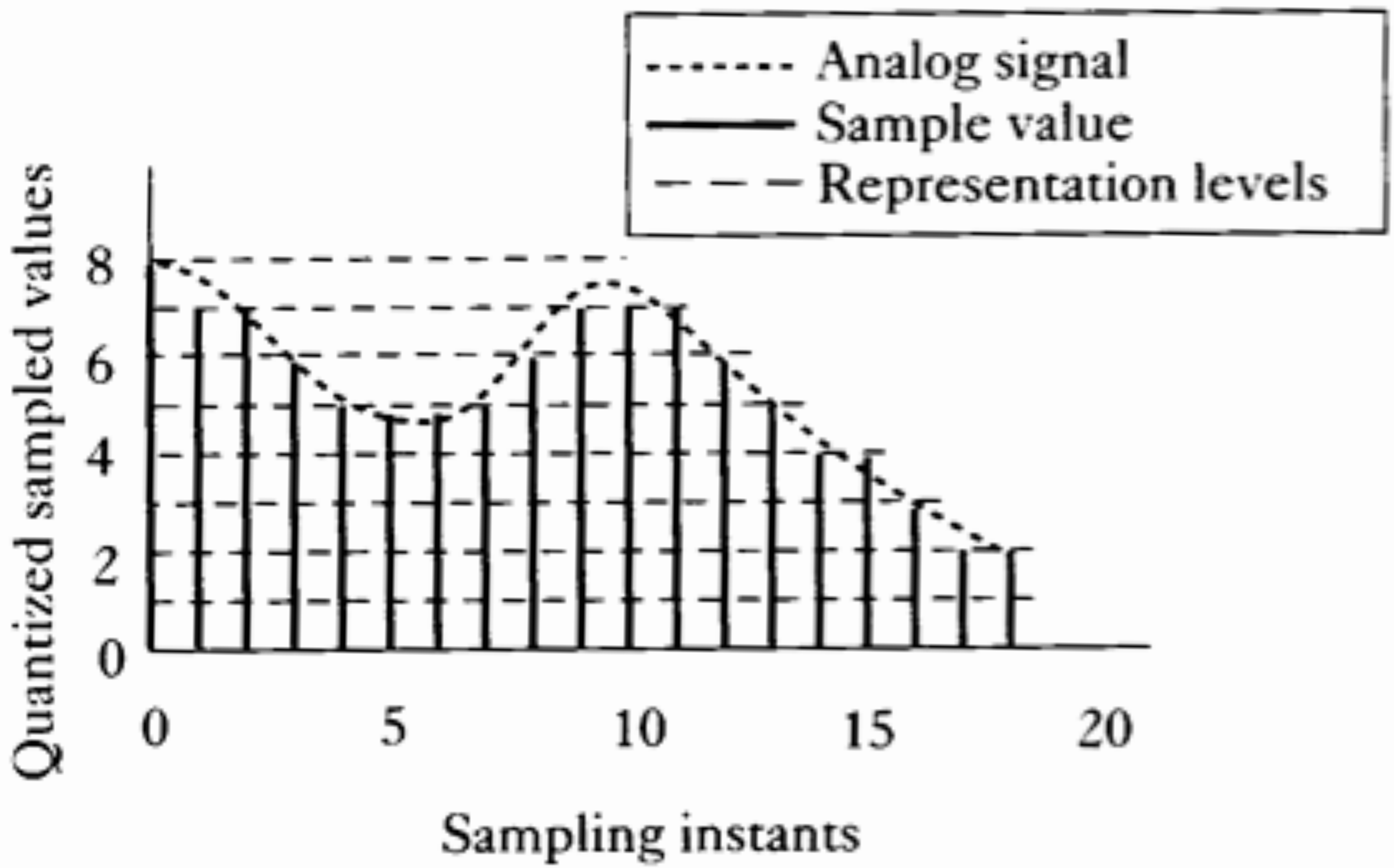
Analog: continuous **Digital: discrete**

TRANSDUCTION. THEN A/D CONVERSION.



http://www.centerpointaudio.com/Images/Analog-Digital%20frequency%20examples.png

A/D CONVERSION BY SAMPLING

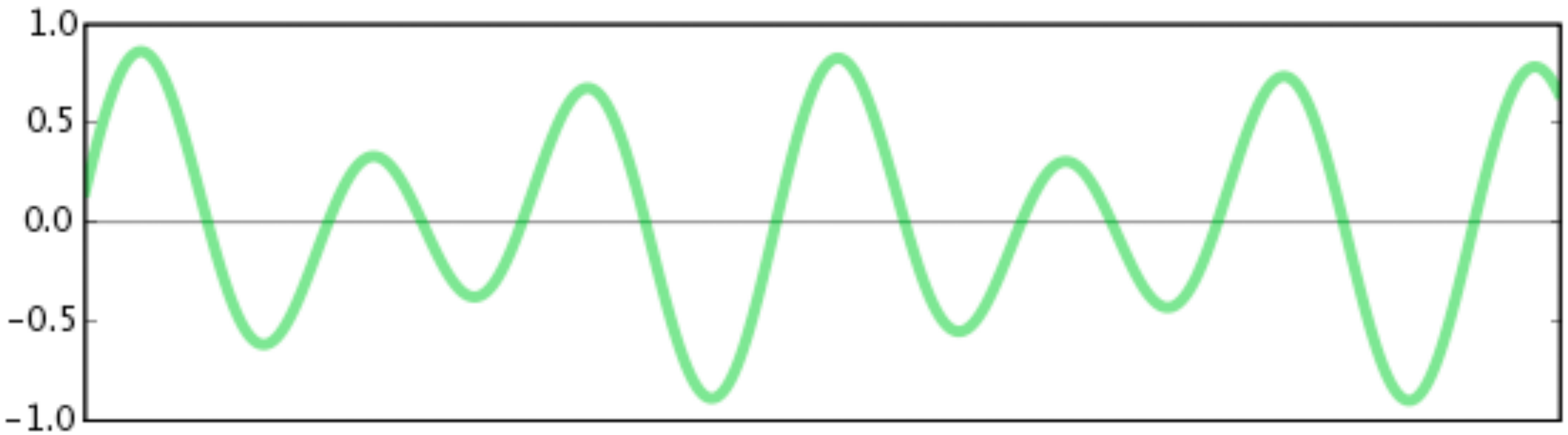


(a) Quantized sampling with 8 representation levels (3 bits per sample).

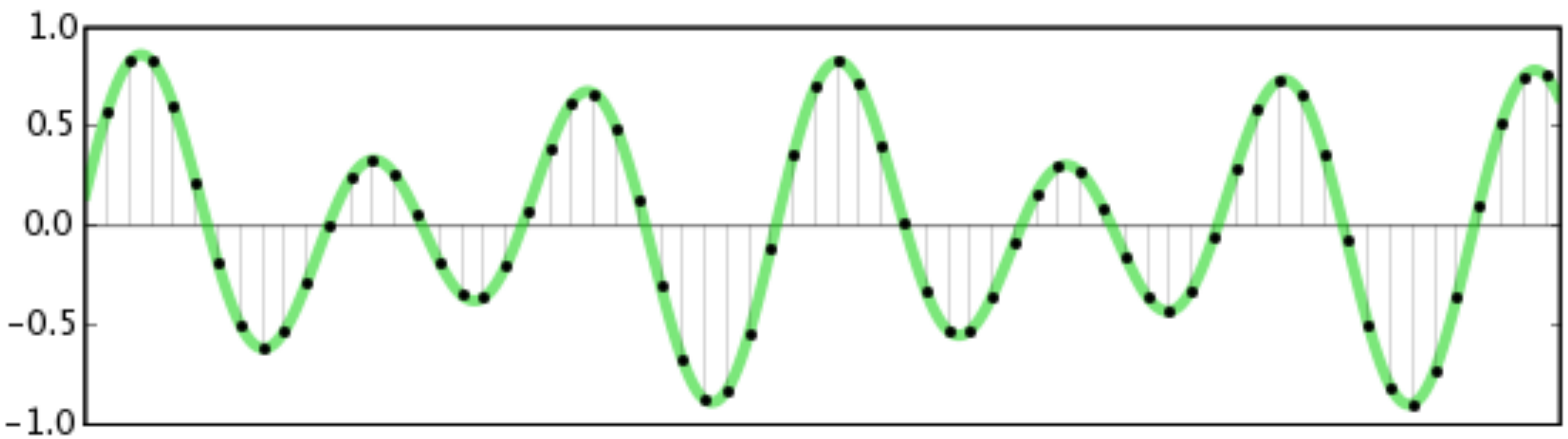
SAMPLING IN TIME

- Horizontal dimension (x-axis) represents time
- Choice for sampling interval: ***at what time interval T are points sampled form the signal?***
    - Every 10 millisecond (ms)? *T = 10ms*
    - Every second (s)? *T = 1s*

EXAMPLE: EVENLY SPACED SAMPLING INTERVALS



Continuous waveform



Sampling values at time interval *T*

http://manual.audacityteam.org/o/man/digital_audio.html

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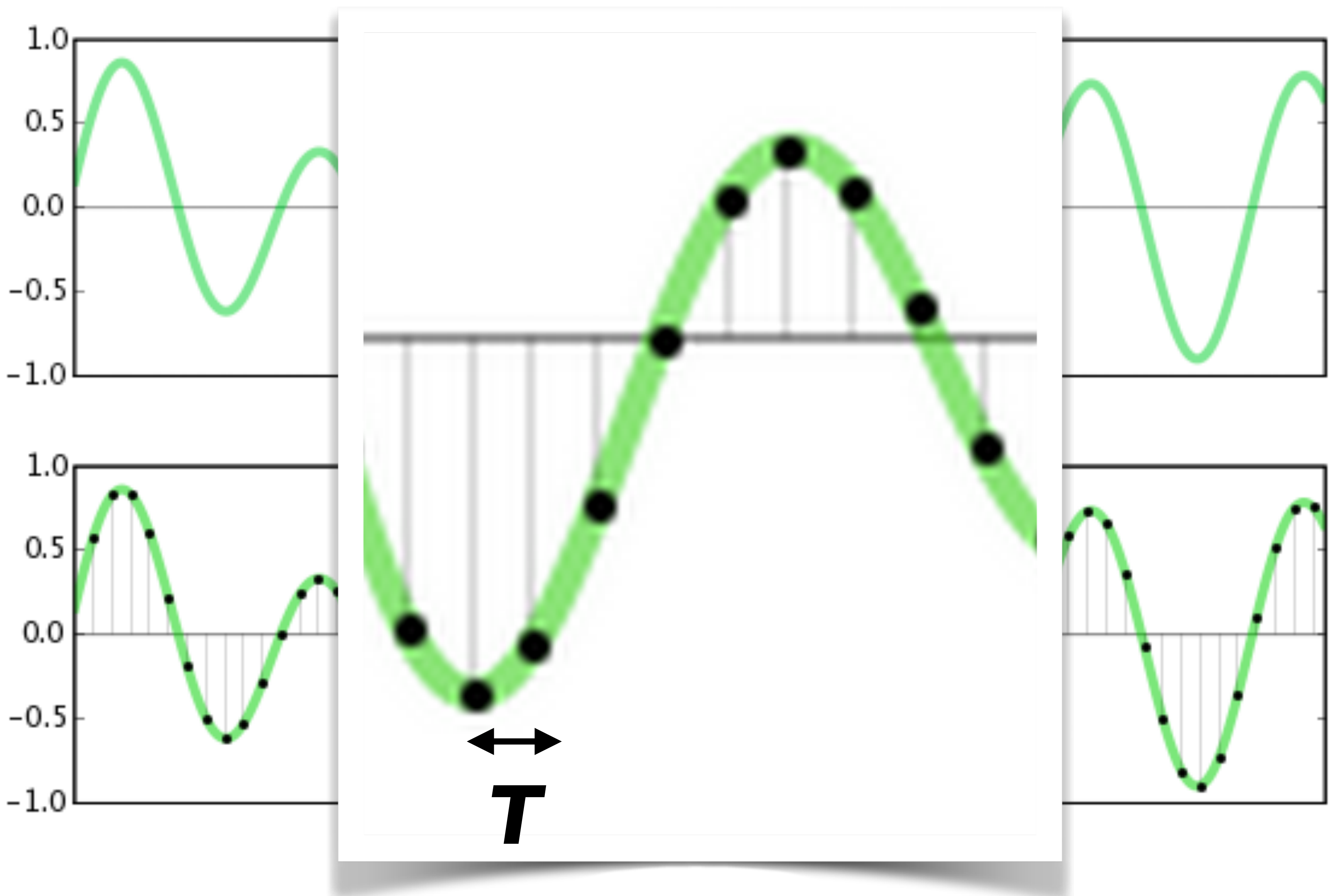


Continuous waveform

Sampling values at time interval *T*

http://manual.audacityteam.org/o/man/digital_audio.html

SAMPLING RATE (OR SAMPLING FREQUENCY)

- **Sampling rate: how frequently, per unit time, are samples taken?**

- Frequency units: typically, the number of samples **per second ("cycles per second").**
- This unit is called **Hertz (Hz)**, cycles per second.
  - Example: "The sampling rate was 20 kilohertz (kHz)" means the sampling rate was 20,000 Hz or 20,000 cycles per second
  - (kilo- = 1000, 1 kHz = 1000 Hz)

CALCULATING SAMPLING RATE

- **Frequency = 1/[time]**
  - *Example: how often do you finish drinking a glass of water?*
  - 1/ [2 hours to finish a glass]

  = 1/2 glass drunk per hour
- **Sampling rate = 1 / [sampling interval] = 1 / T**
  - *Example: if T = 10ms, sampling rate is 1 / 10 ms, "1/10 of a cycle every millisecond"*
  - *Example: if T = 10s, sampling rate is 1/ 10 s, "1/10 of a cycle every second", 0.1 Hz*
- Hz = cycles/second, so…

sampling rate in Hz = 1 / sampling interval in seconds*

*** "seconds" is usually just abbreviated as "s"**

EXERCISE: CONVERTING FROM INTERVAL TO FREQUENCY

- 1 sample every second:
  - sampling interval T = *1s*
  - sampling rate f = *1 Hz*
- 1 sample every 0.1 second:
  - sampling interval T = **?** *s*
  - sampling rate f = **?** *Hz*
- 1 sample every 0.01 second:
  - sampling interval T = **?** *s*
  - sampling rate f = **?** *Hz*

EXERCISE: SAMPLING INTERVALS IN MILLISECONDS

- 1 millisecond = 1 msec
  = 1 ms
  = 0.001 s (= 1/1000 s)

- 1 sample every millisecond:
  - How many samples per second?
  - sampling interval T = **?** *s*
  - sampling rate f = **?** *Hz*

EXERCISE: SAMPLING AT DIFFERENT RATES

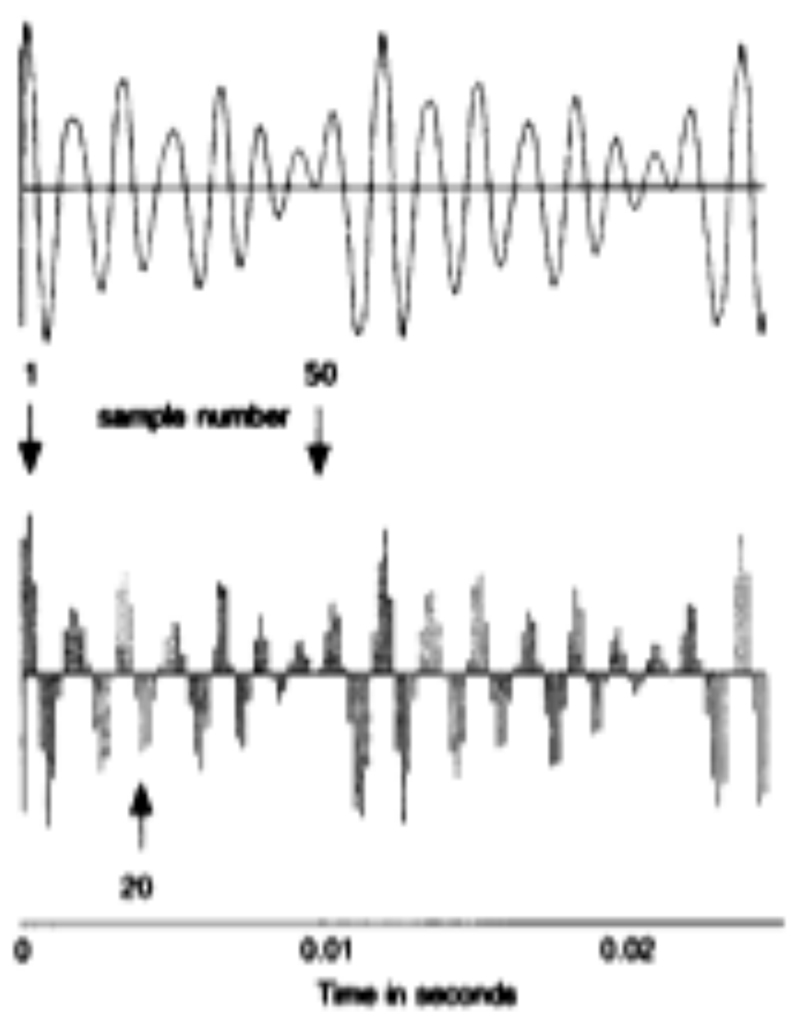
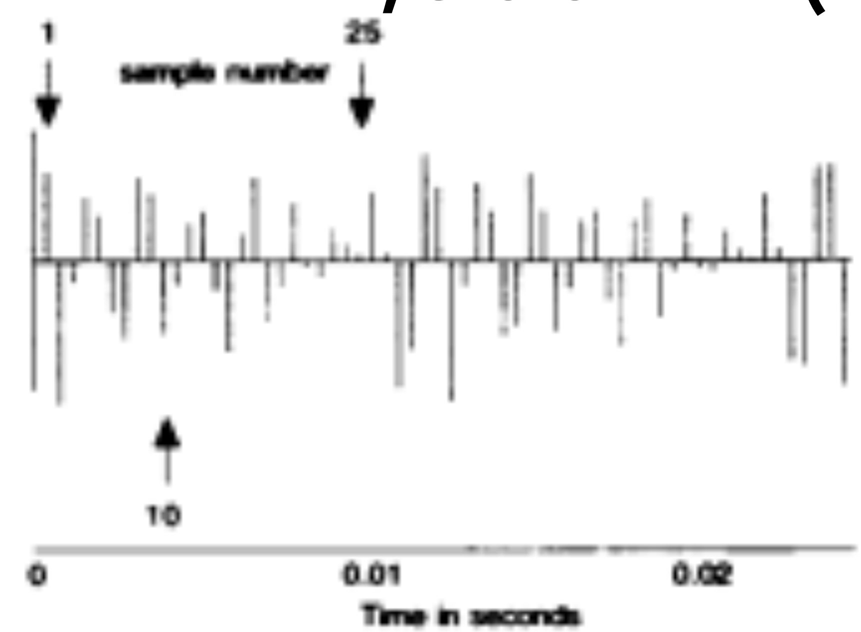


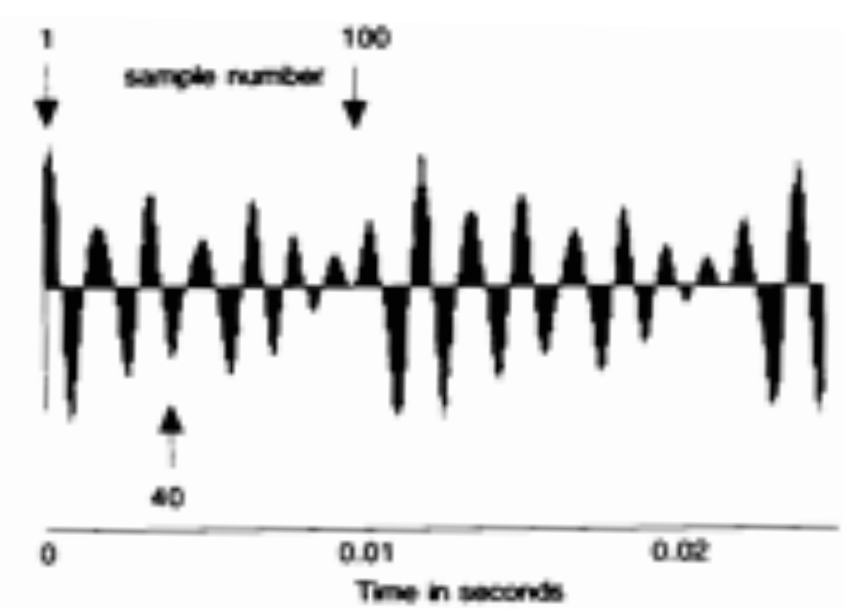
Fig. 9.1. Top: a continuously varying voltage recorded during the production of the vowel [ɑ]; below: lines corresponding to the size of this voltage (the amplitude) at regular intervals of time.

(A/D) →

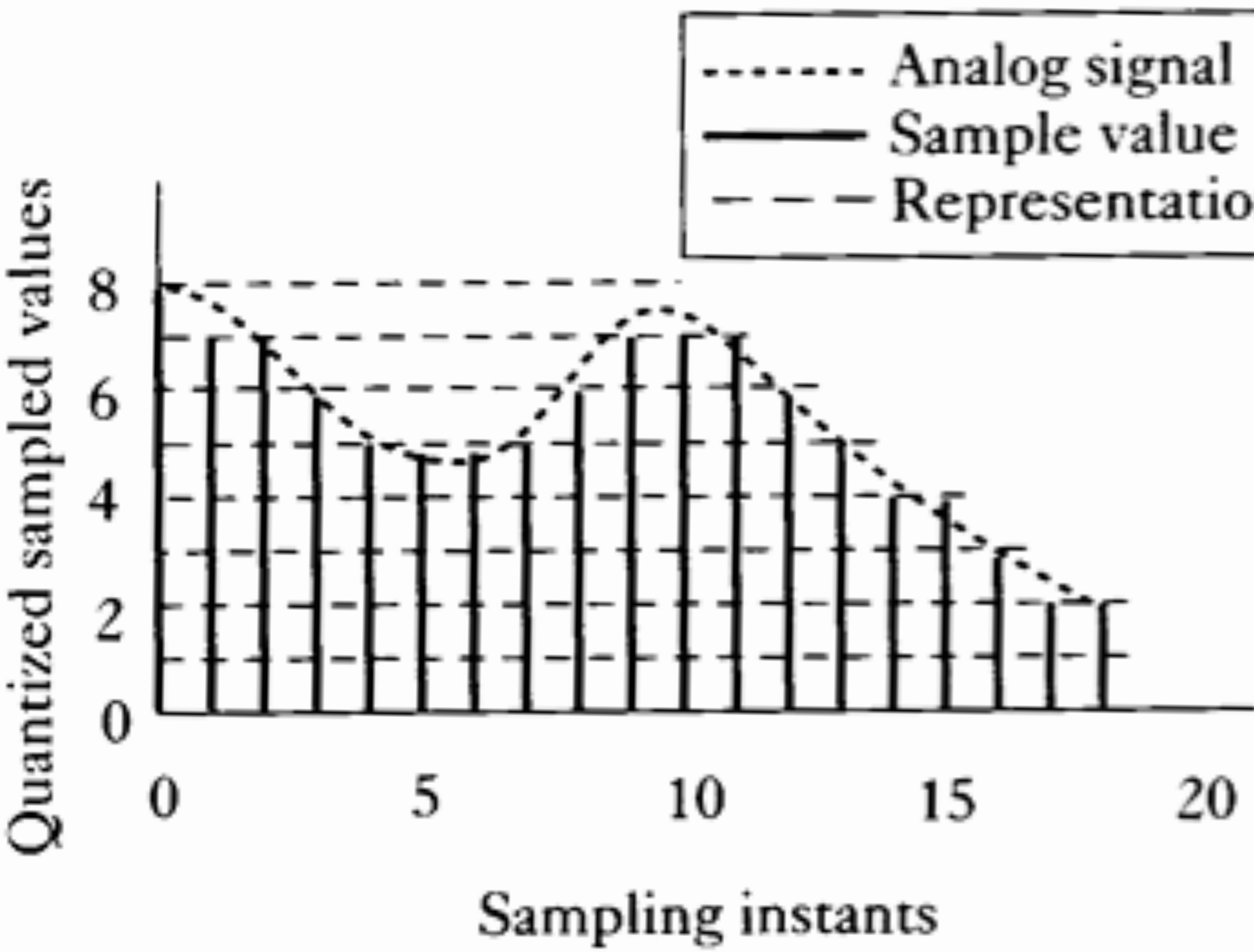
2,500 Hz (? kHz)



10,000 Hz (? kHz)



QUANTIZATION: "SAMPLING" AMPLITUDE



(a) Quantized sampling with 8 representation levels (3 bits per sample).

Vertical dimension (y-axis) is divided into some number of values: here, 8 values (2^3)

Quantization rate (bit depth) = 3 bits

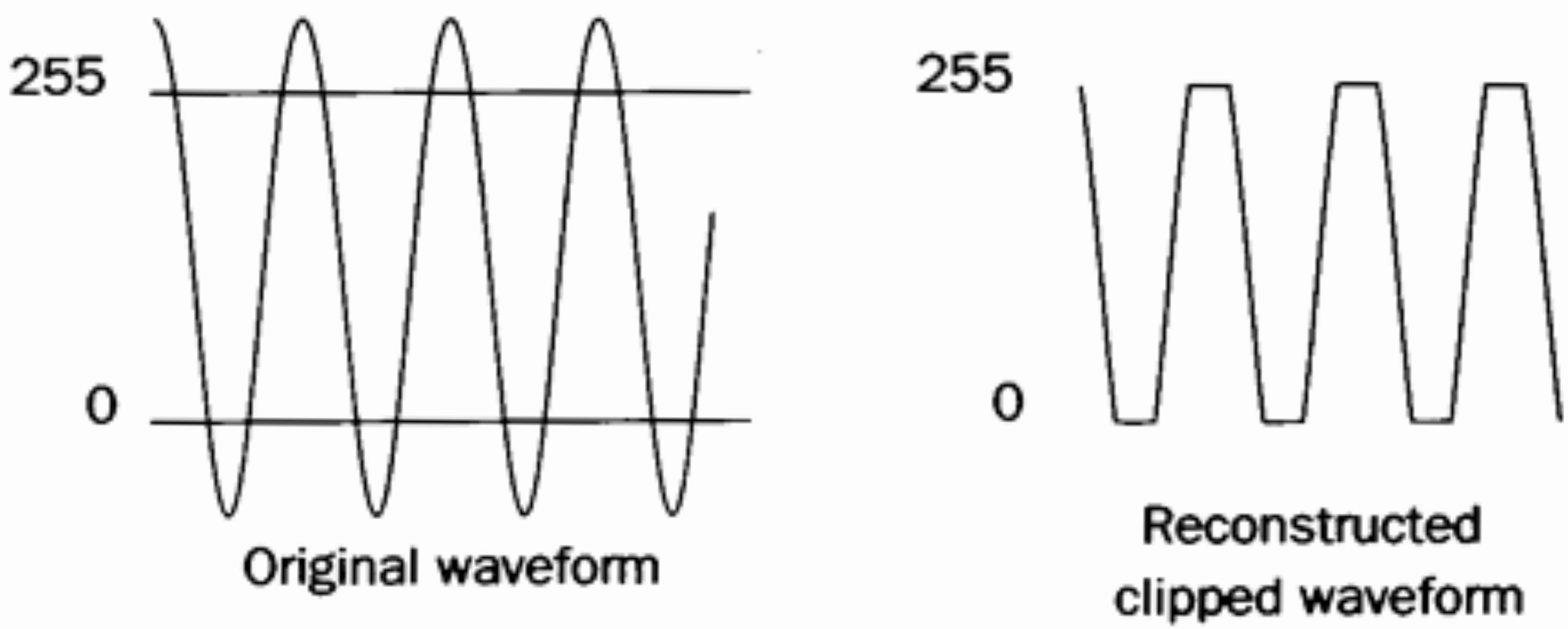
EXERCISE: QUANTIZATION RATE (BIT DEPTH)

- Divide amplitude range into 65,536 values
  - 65,536 $= 2^{16}$
  - Quantization rate = **?** bits
- Divide amplitude range into 4096 values
  - $4096 = 2^{?}$
  - Quantization rate = **?** bits
- Quantization rate = 4 bits
  - Amplitude range divided into **?** values

CLIPPING

Clipping: the peak amplitude of the sample is greater than the largest amplitude allowed by the quantization.

You can minimize the amount of clipping when recording by adjusting the input level.



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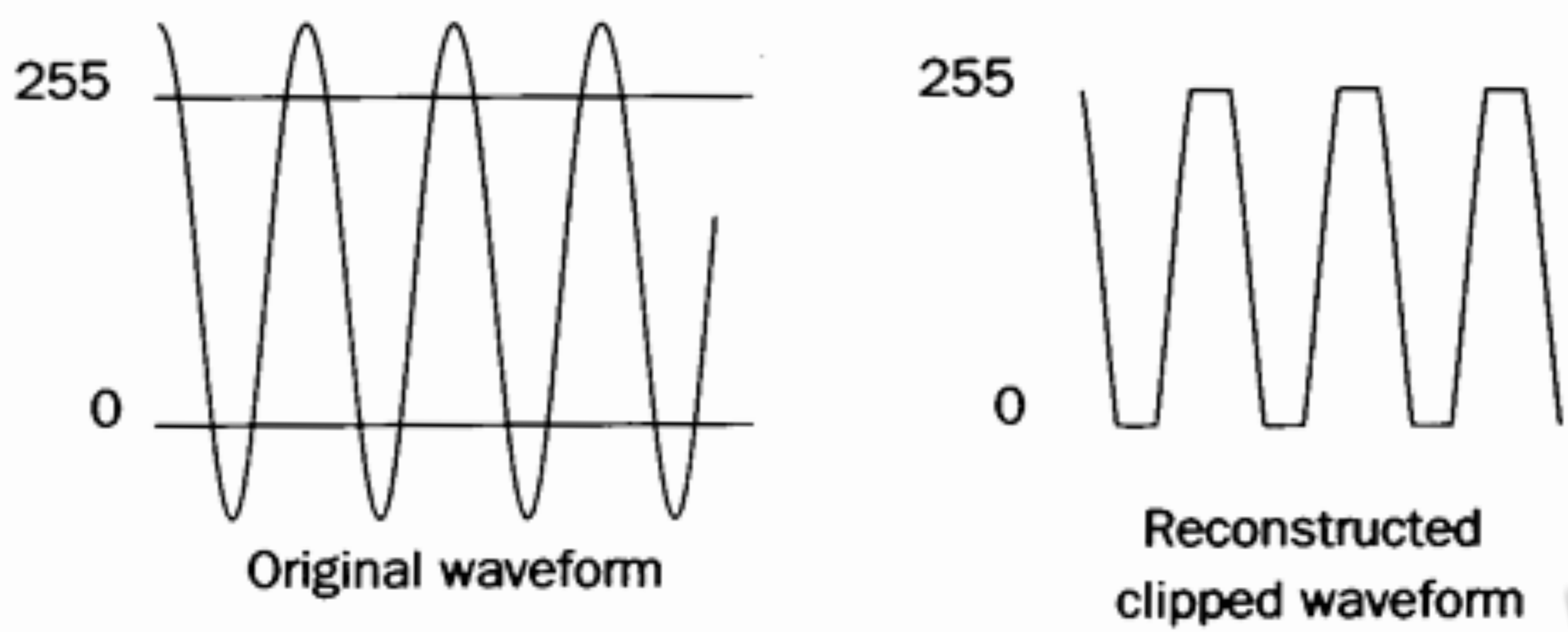
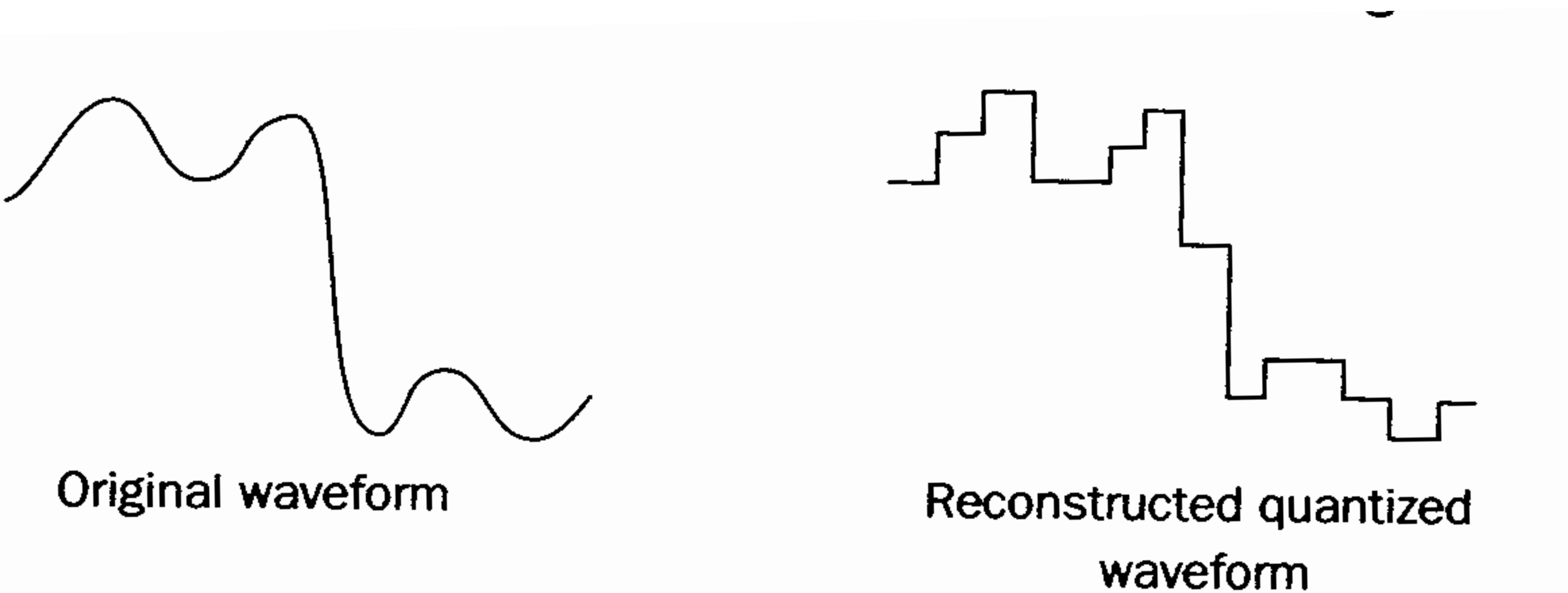


Class demo!

TOO FEW AMPLITUDE LEVELS?



MORE SAMPLES ⇒ BETTER AUDIO QUALITY

- Higher **sampling** rate gives better **time** resolution
- Higher **quantization** rate gives better **amplitude** resolution

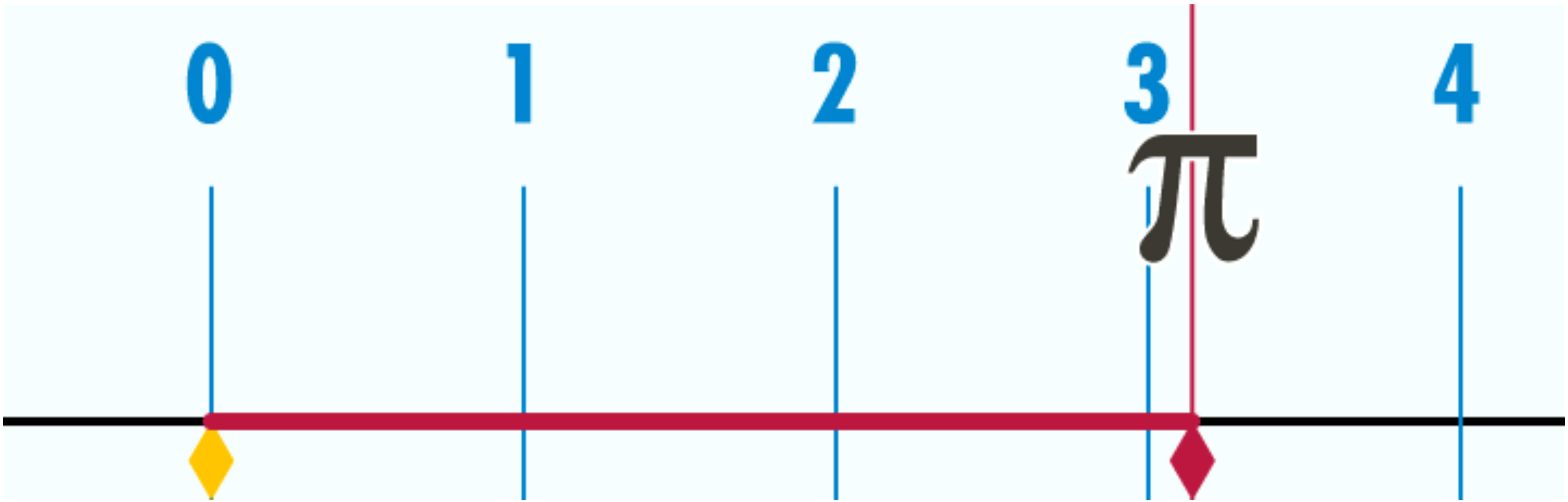
WHY NOT EVEN HIGHER RATES?

Trade-off between fidelity to original signal and demands on memory and processing of the stored string of numbers

- Higher sampling rate: more numbers to be stored, retrieved and processed
- Higher quantization rate: bigger numbers to be stored, retrieved, and processed

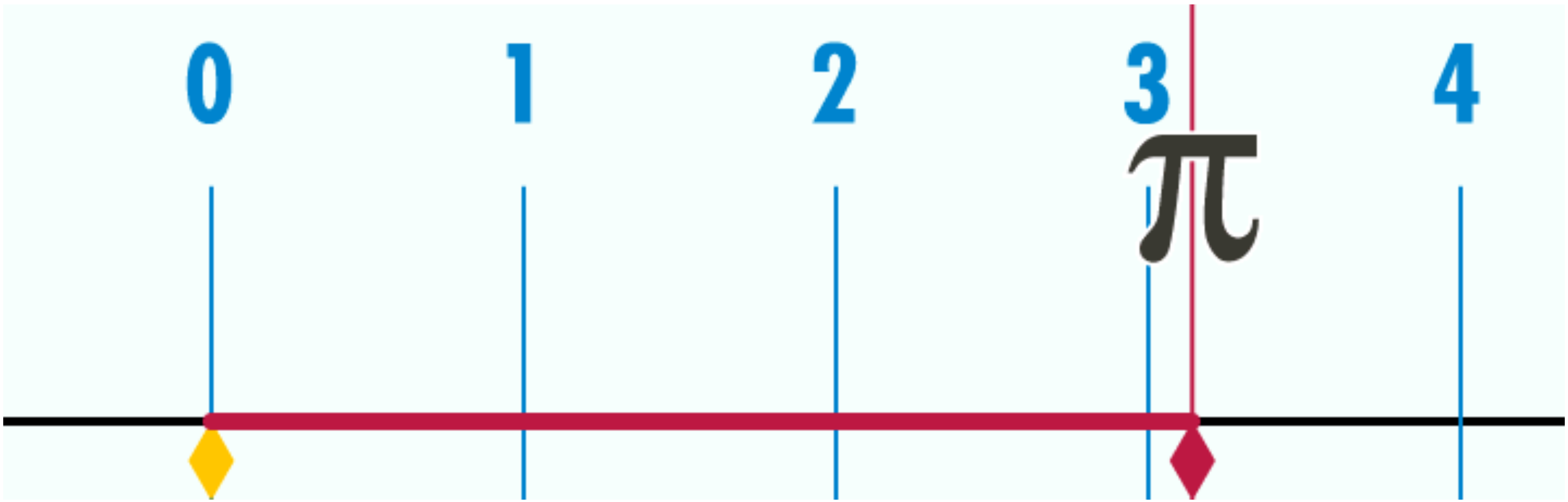
COOL TRIGONOMETRIC ANIMATED GIFS

WHAT IS PI?



https://upload.wikimedia.org/wikipedia/commons/2/2a/Pi-unrolled-720.gif

WHAT IS PI?



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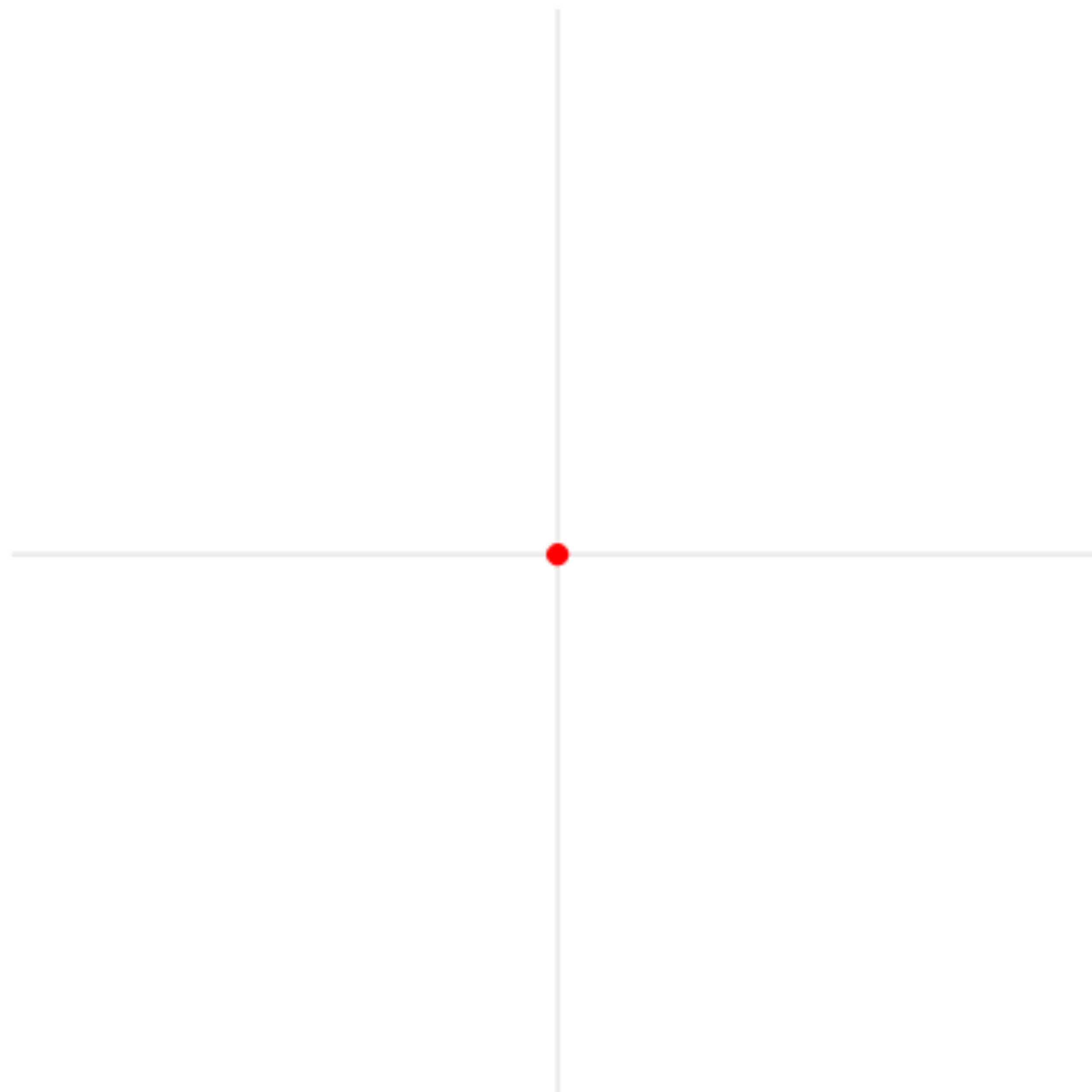
ANGULAR FREQUENCY AND RADIANS



https://upload.wikimedia.org/wikipedia/commons/4/4e/Circle_radians.gif'

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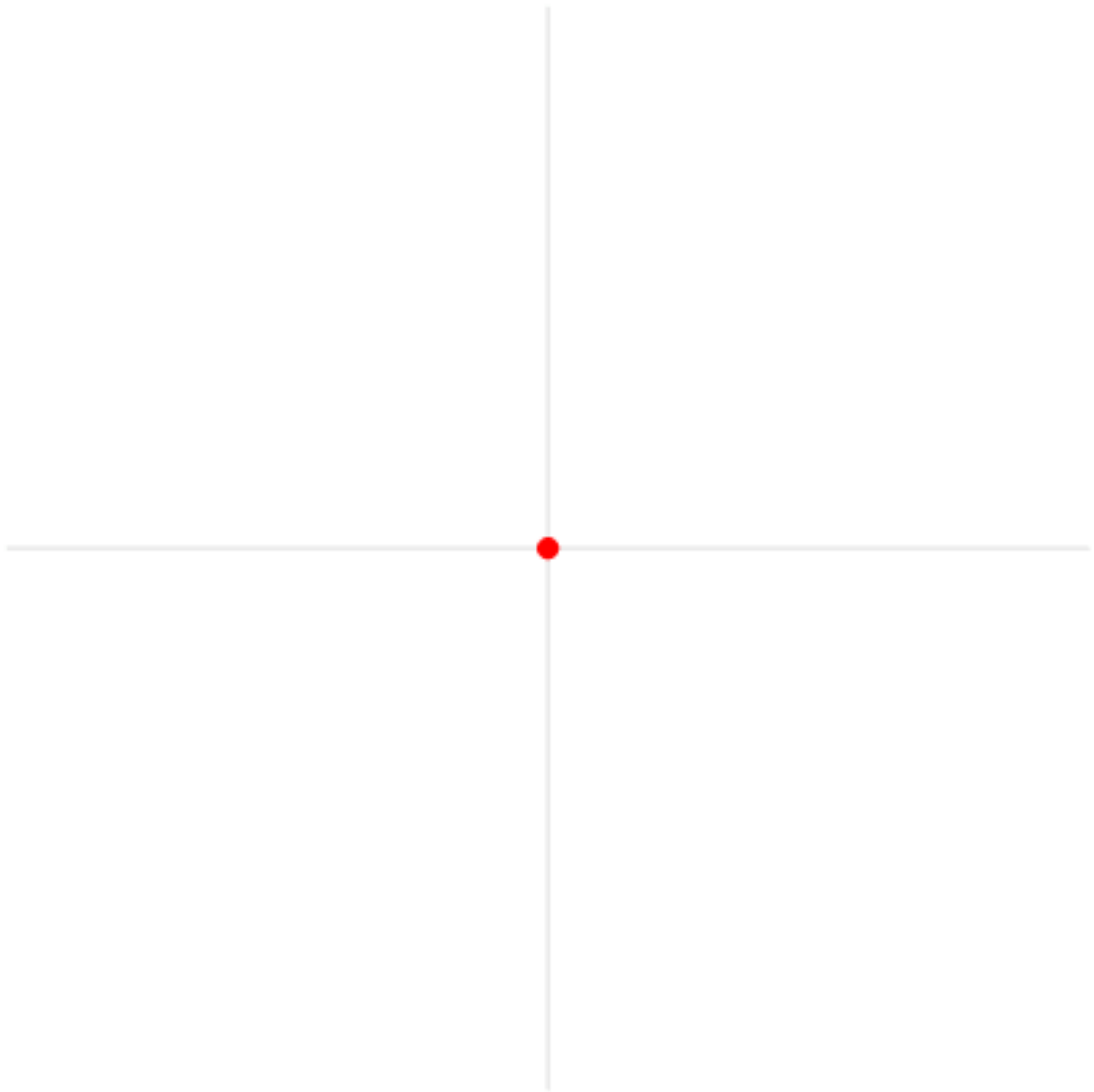

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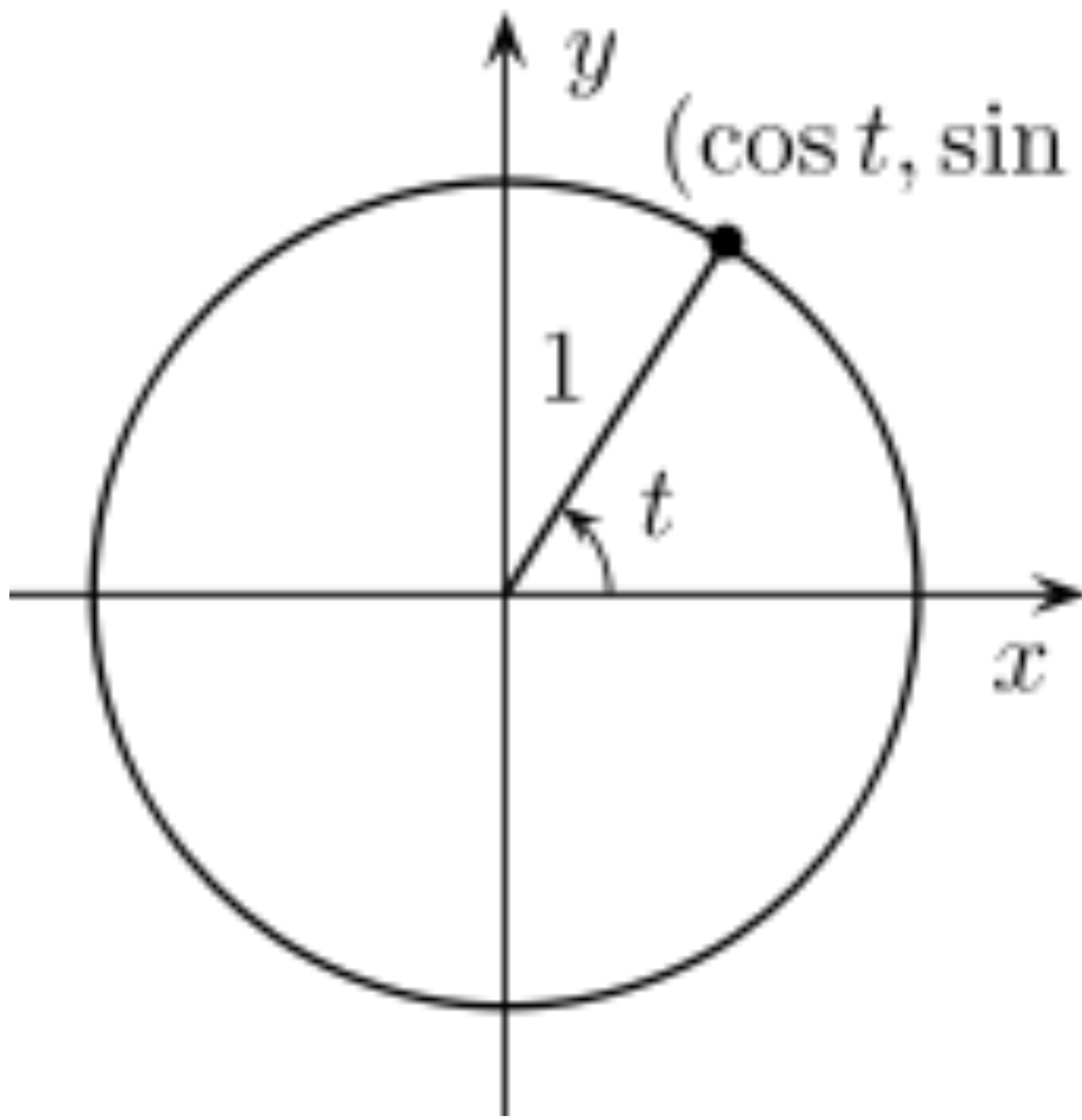
SINE, COSINE, AND THE UNIT CIRCLE



https://openlab.citytech.cuny.edu/ganguli-mat1375-fall2015/files/2015/11/186px-Unit_circle.svg_.png

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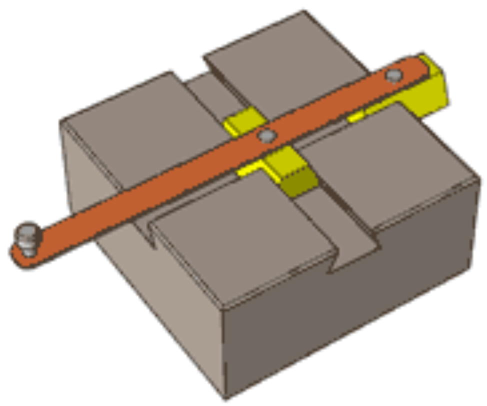

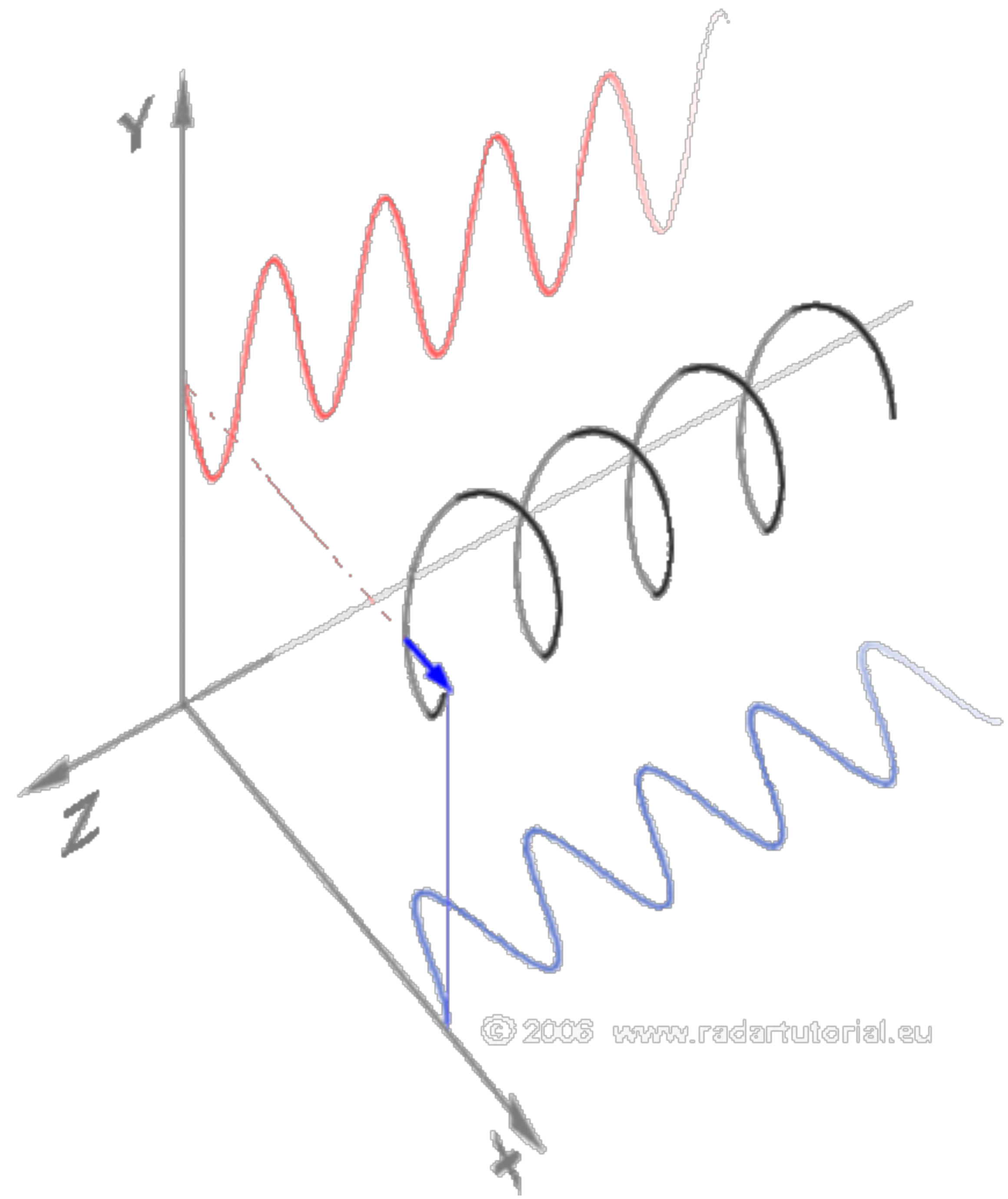

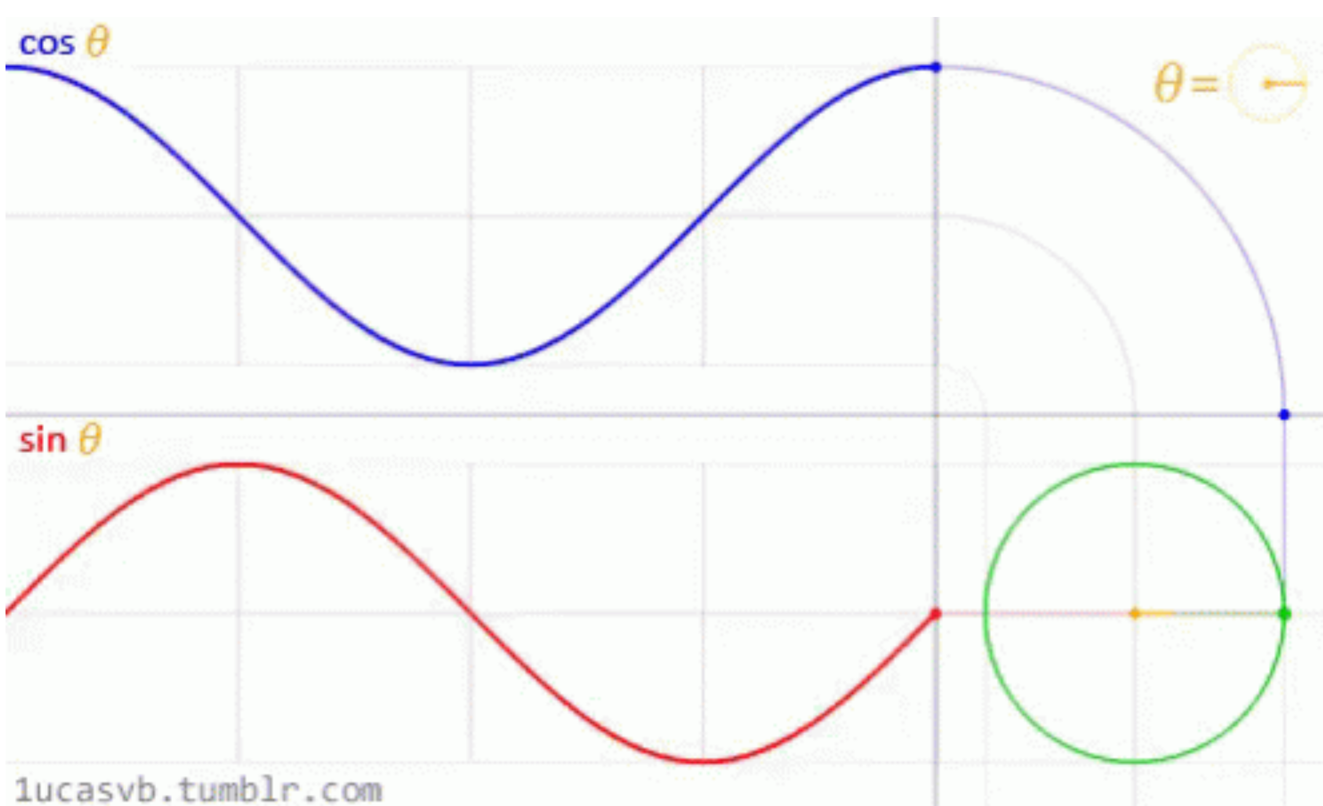

http://www.businessinsider.com/7-gifs-trigonometry-sine-cosine-2013-5
https://commons.wikimedia.org/wiki/File%3ACircle_cos_sin.gif

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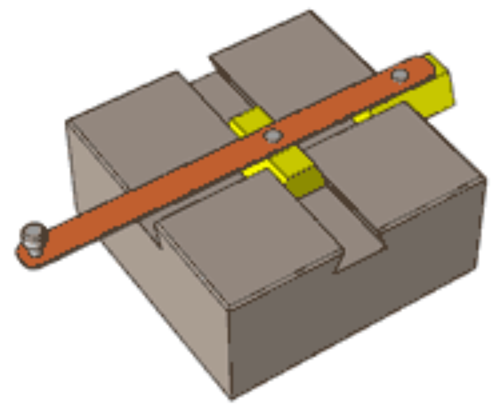

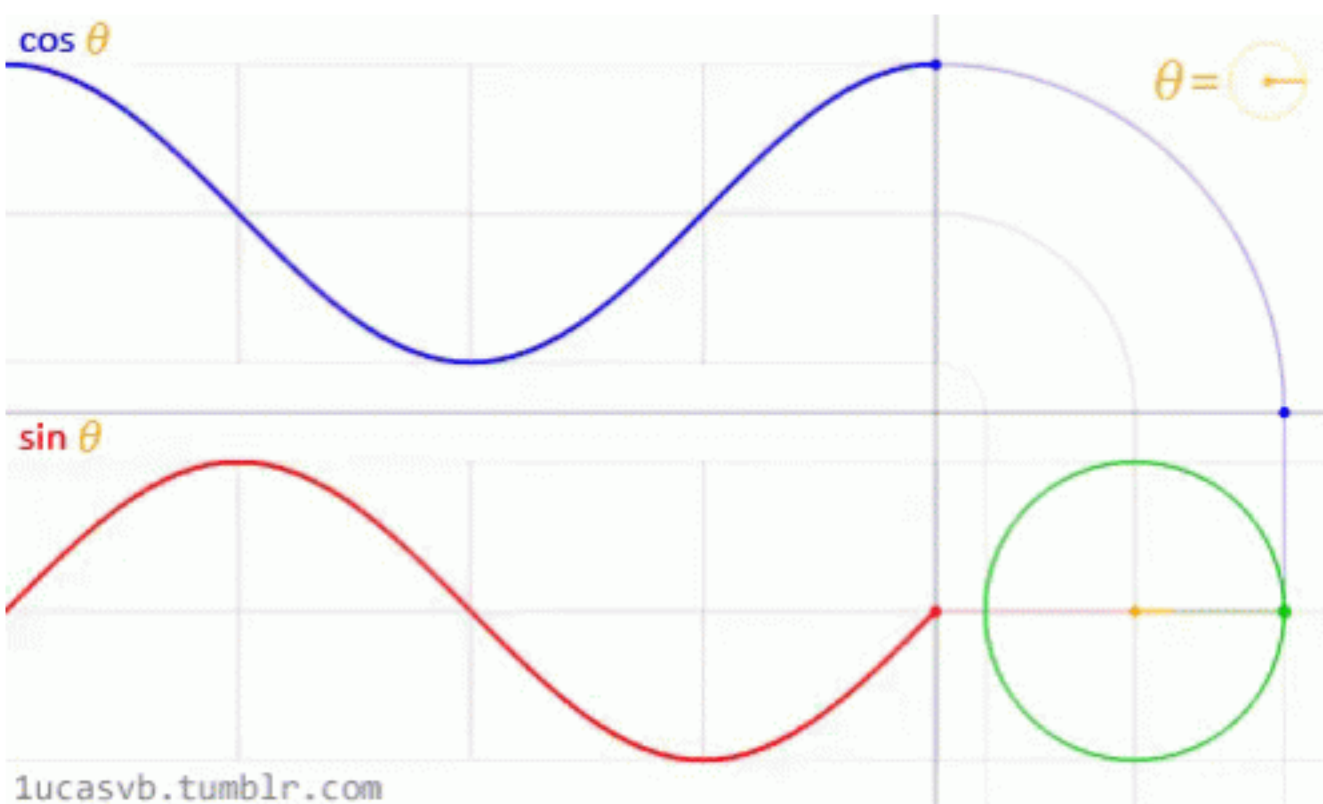

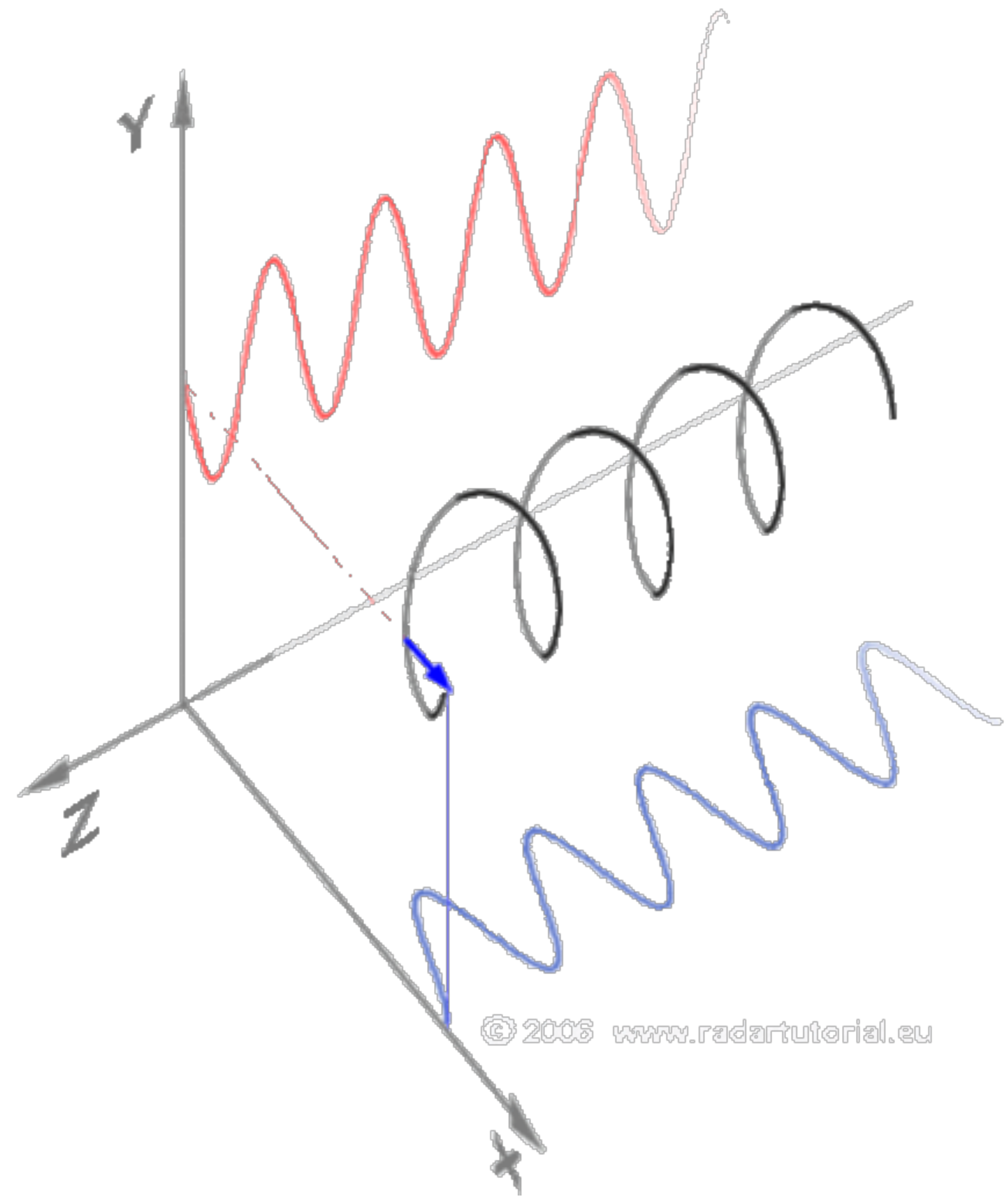

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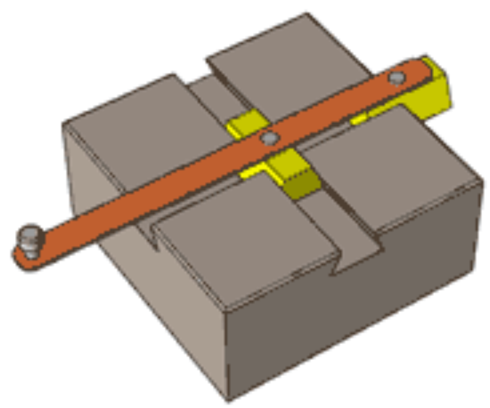

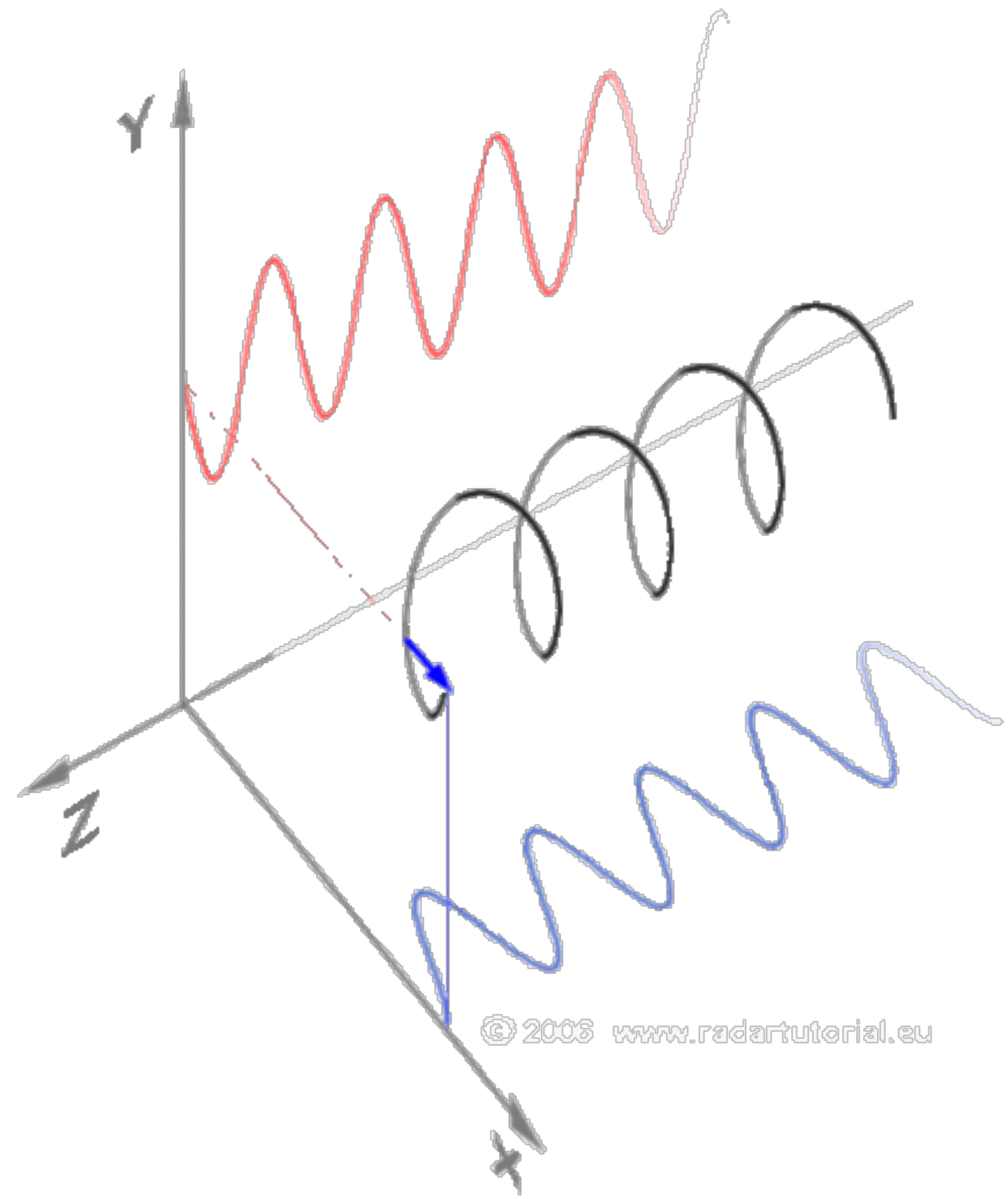

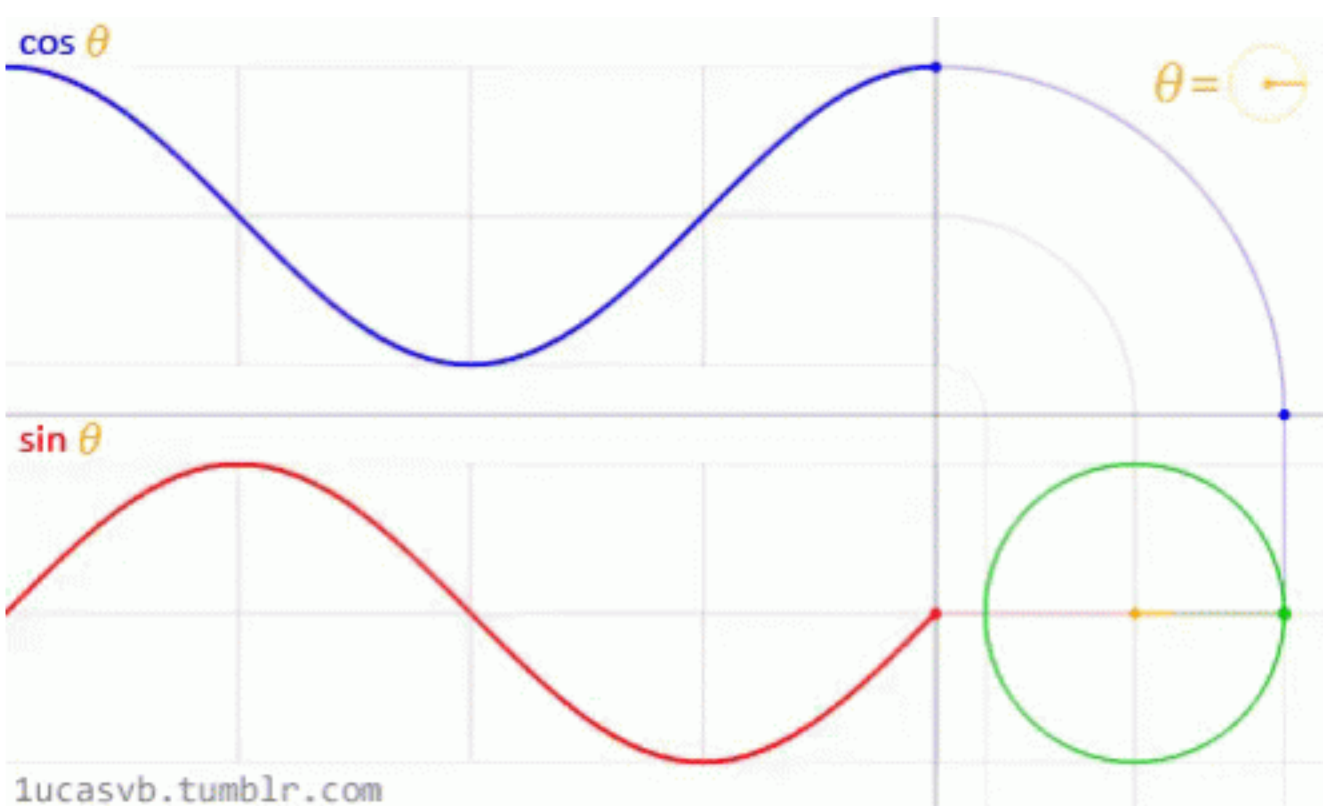

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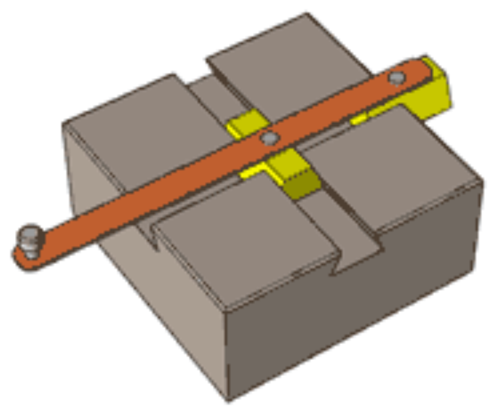

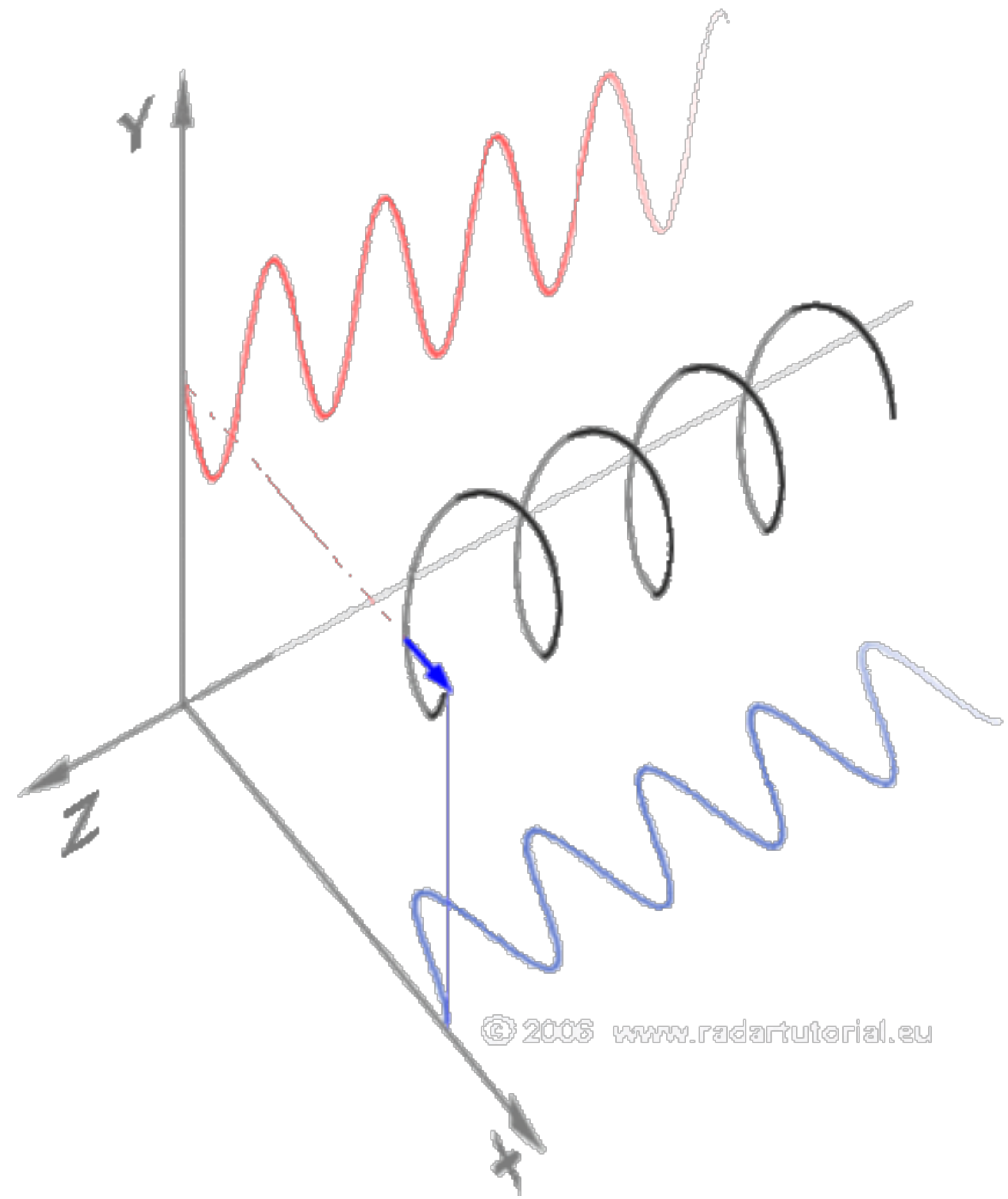

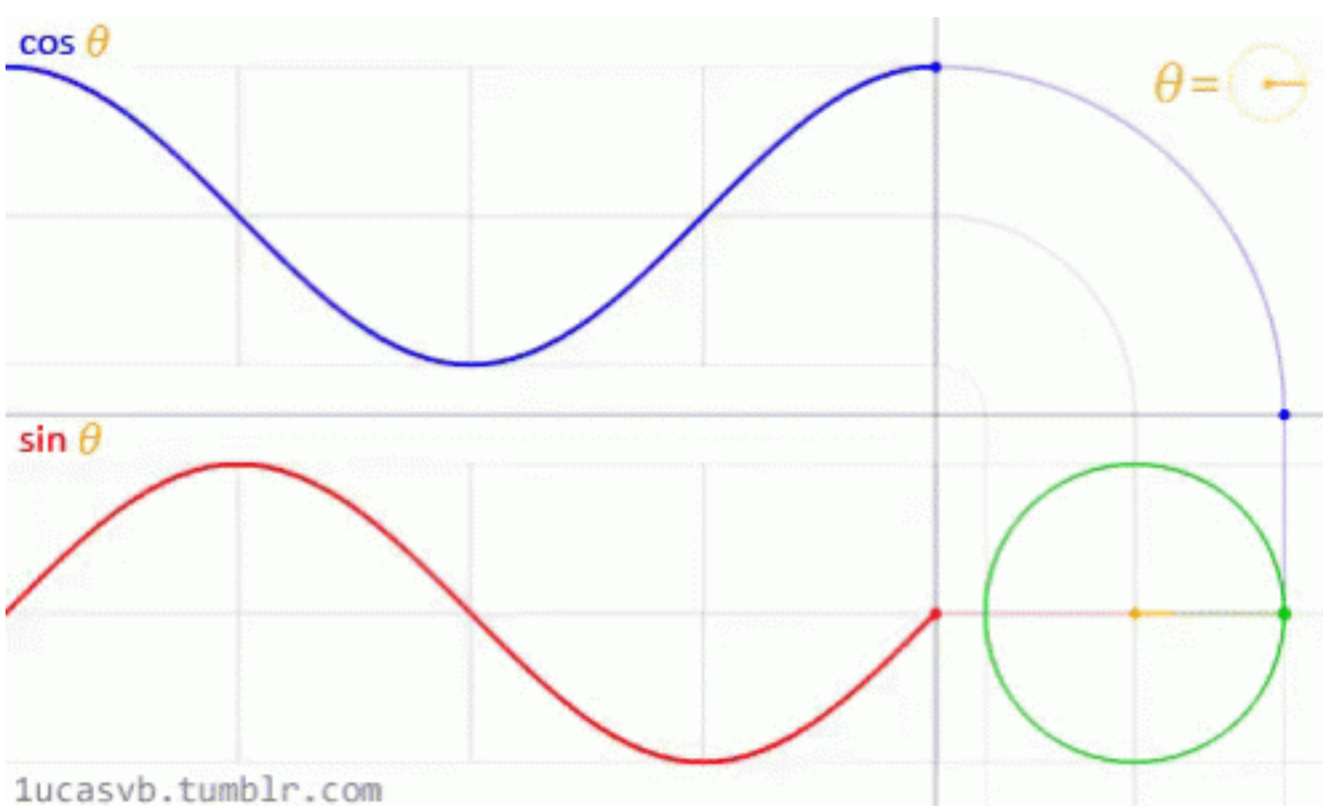

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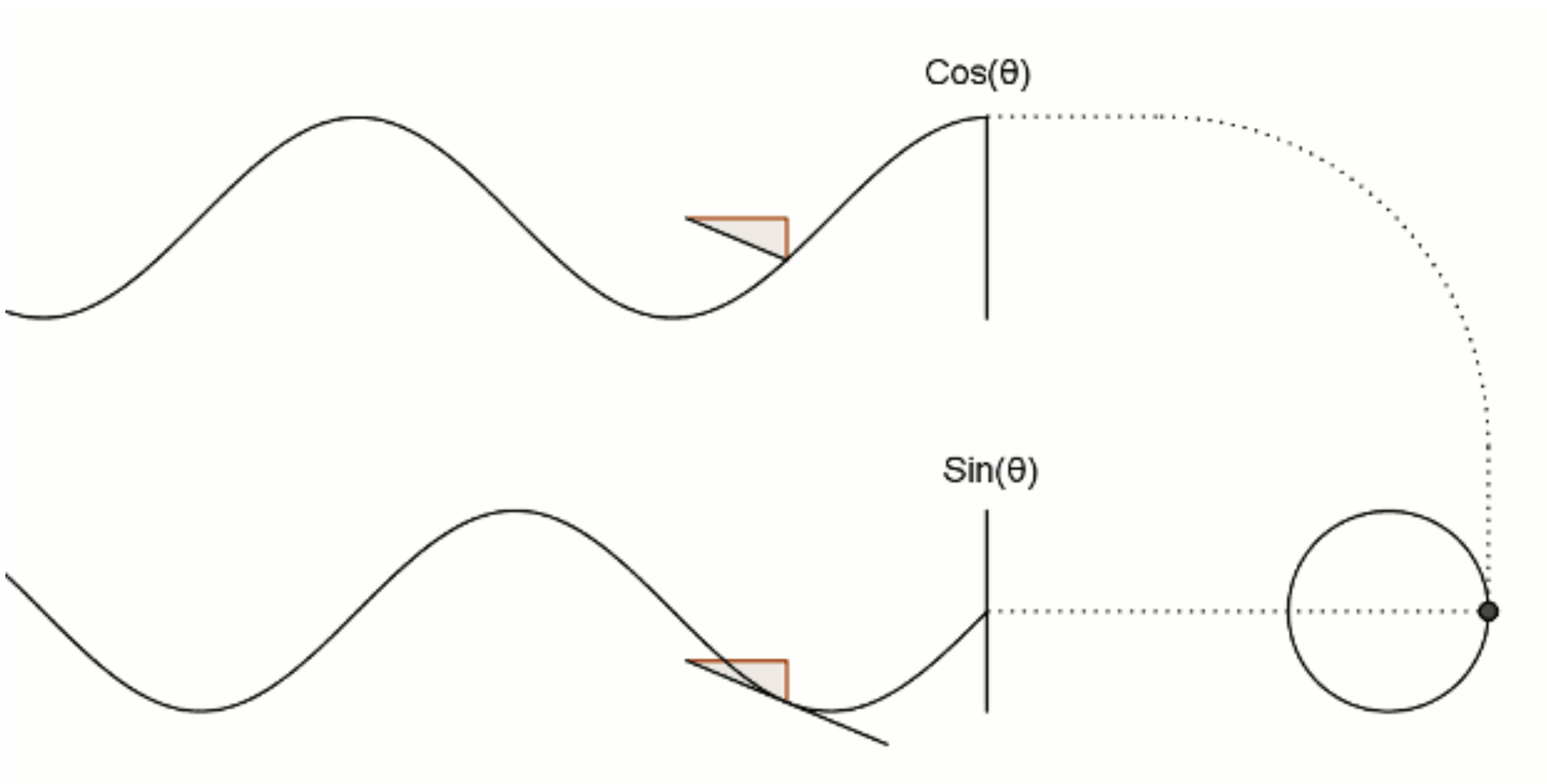
SINUSOIDS, CIRCLES, AND TRIANGLES



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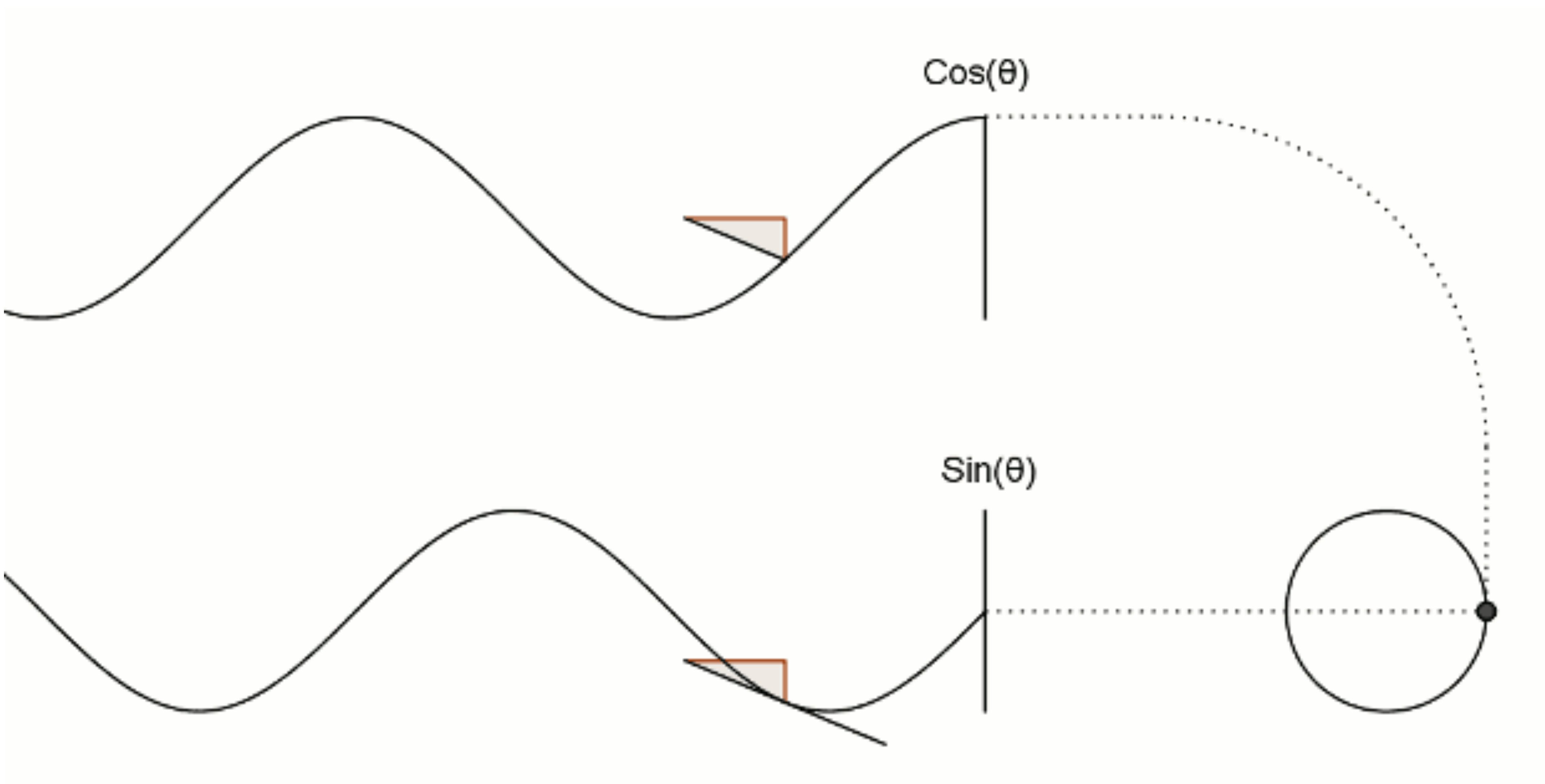

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