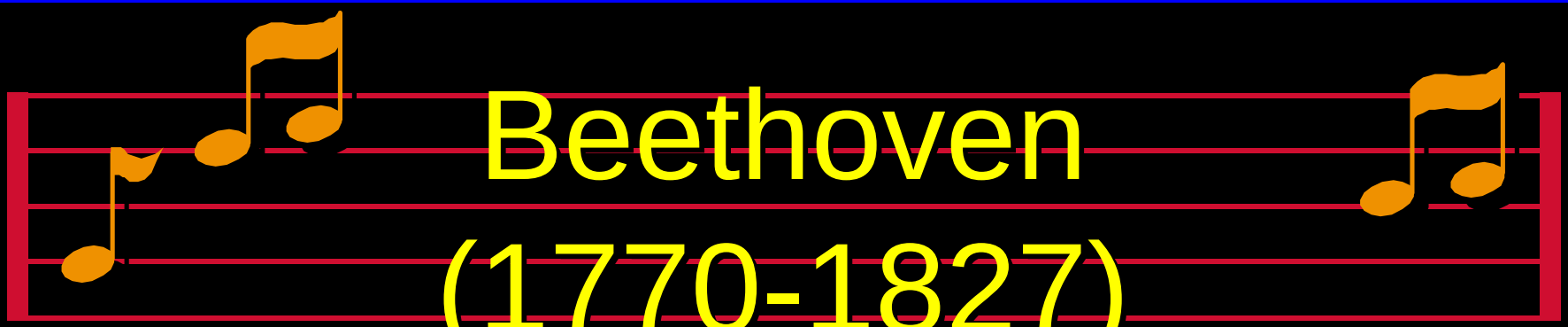


Beethoven (1770-1827)

String Quartet in F major Op. 18, No. 1

http://science.widener.edu/~panek/130/130.html

Five Components of Instruments

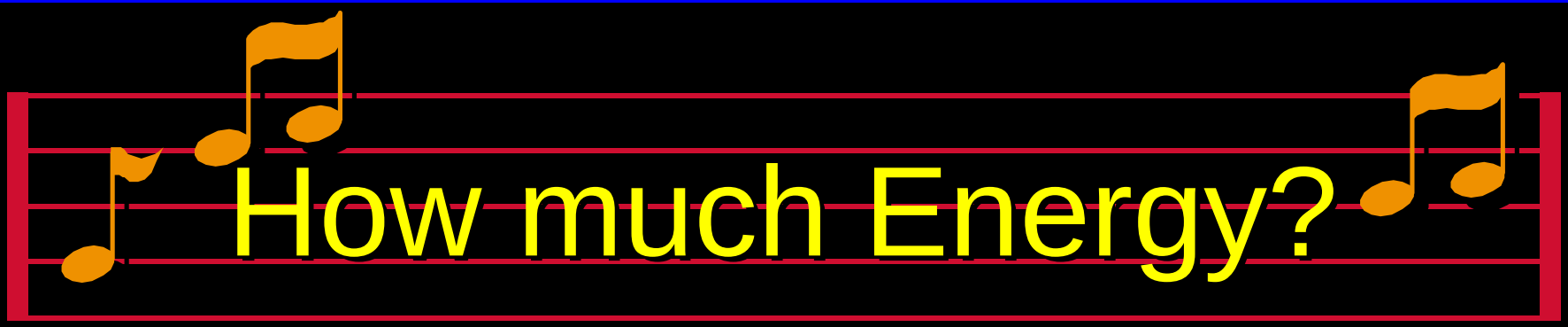
1. Energy source
2. Energy connector from the source to the instrument itself

Components of Instruments

3. Primary oscillator
4. Resonant oscillator
5. Sound emitter

1. Energy Source

- Muscle Power
  - Arm Motion
  - Finger Motion
  - Lung Motion
  - Foot Motion
- Electrical Power



- Typical Instrument = 50W
- ~ 1% is converted to sound
- Total Orchestra ~ 60W
- For 90 dB = 10^{-3} W/m^2 at an ear of 1 cm^2 P=10^{-7} W!!

2. Energy Connector

- Transmits from Source to the instrument itself
- Examples:
  - Violin family
  - Piano
  - Wind Instruments
  - Organ

3. Primary Oscillator

- The part of the instrument that vibrates and is directly responsible for the sound.
- Examples:
  - Strings, reeds, lips, surfaces, air.

4. Resonant Oscillator

- Amplifies certain frequencies to produce a harmonic series.
- Examples:
  - Violin family
  - Piano
  - Winds
  - Drums

5. Sound Emitter

- Gets the sound out. Usually via a hole or opening
- Examples:
  - Violin family
  - Piano
  - Winds
  - Drums

String Instruments

1. Energy Source
   - Arm motion for bowing
   - Finger motion for plucking (violin or guitar) or moving keys (piano)

String Instruments

2. Energy Connector

- Bows
- Hammers
- Picks or Quills
- Fingers

String Instruments

3. Primary Oscillator Strings

$$\frac{f_2}{f_1} = \sqrt{\frac{W_1}{W_2}}$$

$$\frac{f_2}{f_1} = \sqrt{\frac{k_2}{k_1}}$$

$$f_n = n(v/2L)$$

String Instruments

- String Variables related to frequency
  - Length
  - Tension
  - Density

String Instruments

- Frequency Variation
  - Many Strings of Different Length, Tension, Density
  - Change Effective Length of String

String Instruments

- Activation Location
  - Changes timbre by reducing some harmonics
  - No nodes at activation points

String Instruments

Nodes at middle of the string

Second Harmonic

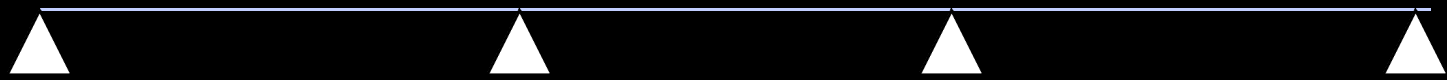
Fourth Harmonic

Sixth Harmonic

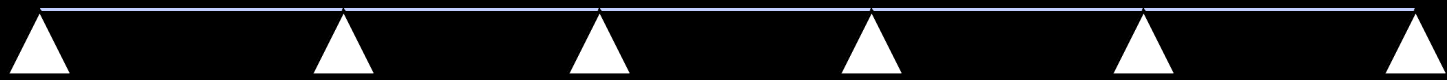
String Instruments

Antinodes at middle of the string

Fundamental



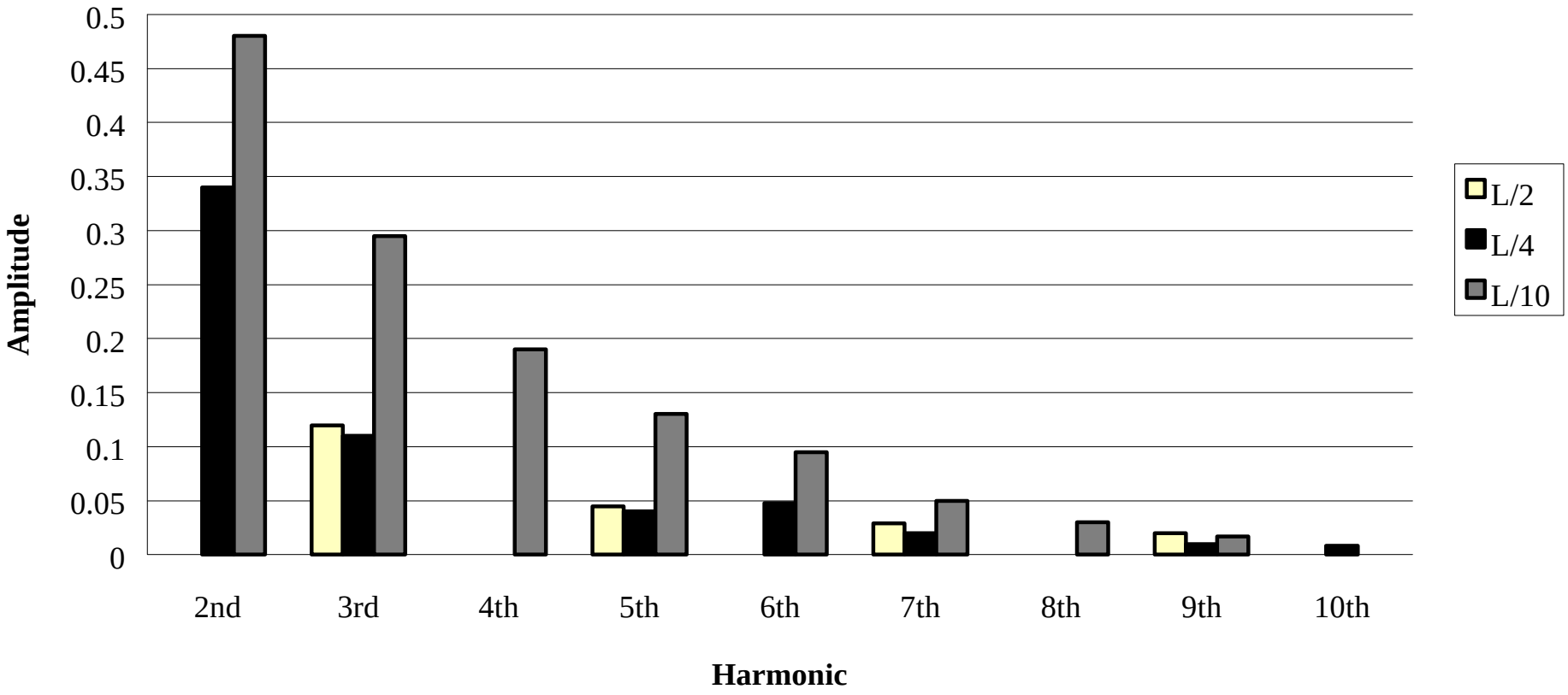
Third Harmonic



Fifth Harmonic

String Instruments

Activation Position and Harmonic Spectra



String Instruments

4. Resonant Oscillator

- Wooden Box or Sheet of Irregular Shape
- Example: Violin (MI CD)

String Instruments

5. Sound Emitter

- Opening in the Body of the Instrument
- Examples: Violin and Guitar, etc.

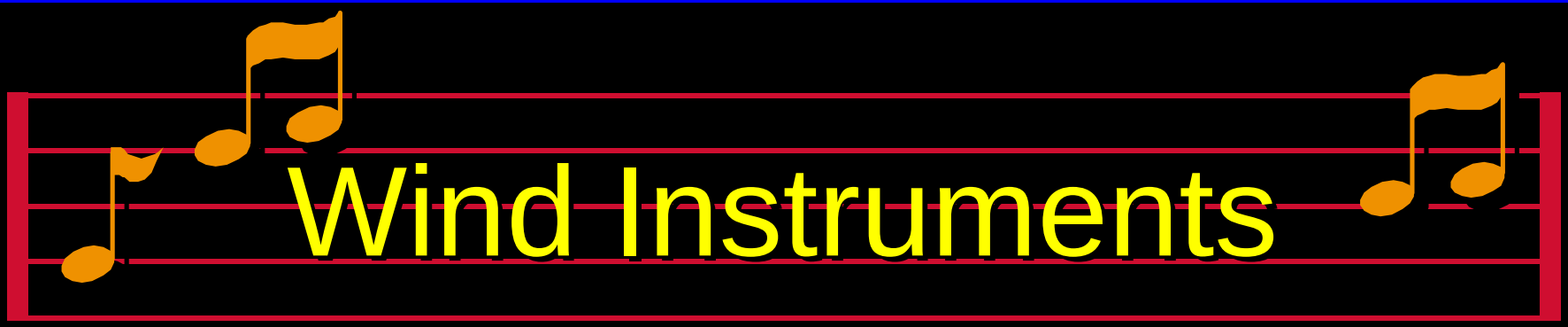
Classical pieces on Soprano Saxophone

String Instruments

Stringed instruments on the MI CD

Wind Instruments

- Energy Source
  - Lungs
- Energy Connector
  - Air From Player's Lungs or From a Compressor



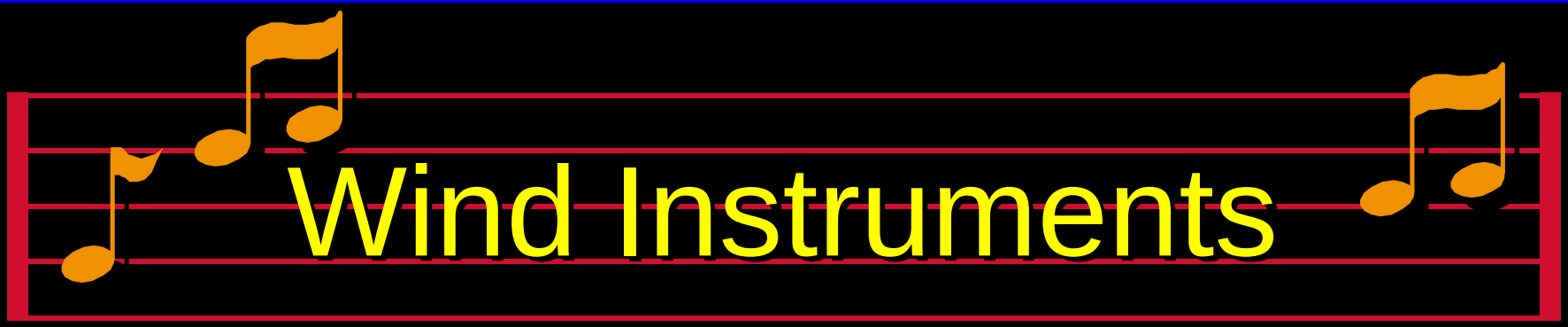
- Primary Oscillator
  - Reed(s)
  - Player's Lips (Brasses)
  - Air Near Opening Into Which Player Blows (Flutes)

Wind Instruments

- Reed: Single and Double
  - Bernoulli effect
  - Alternating high and low pressure
  - Examples: clarinets, oboes, saxophones, bag pipes, accordians

Wind Instruments

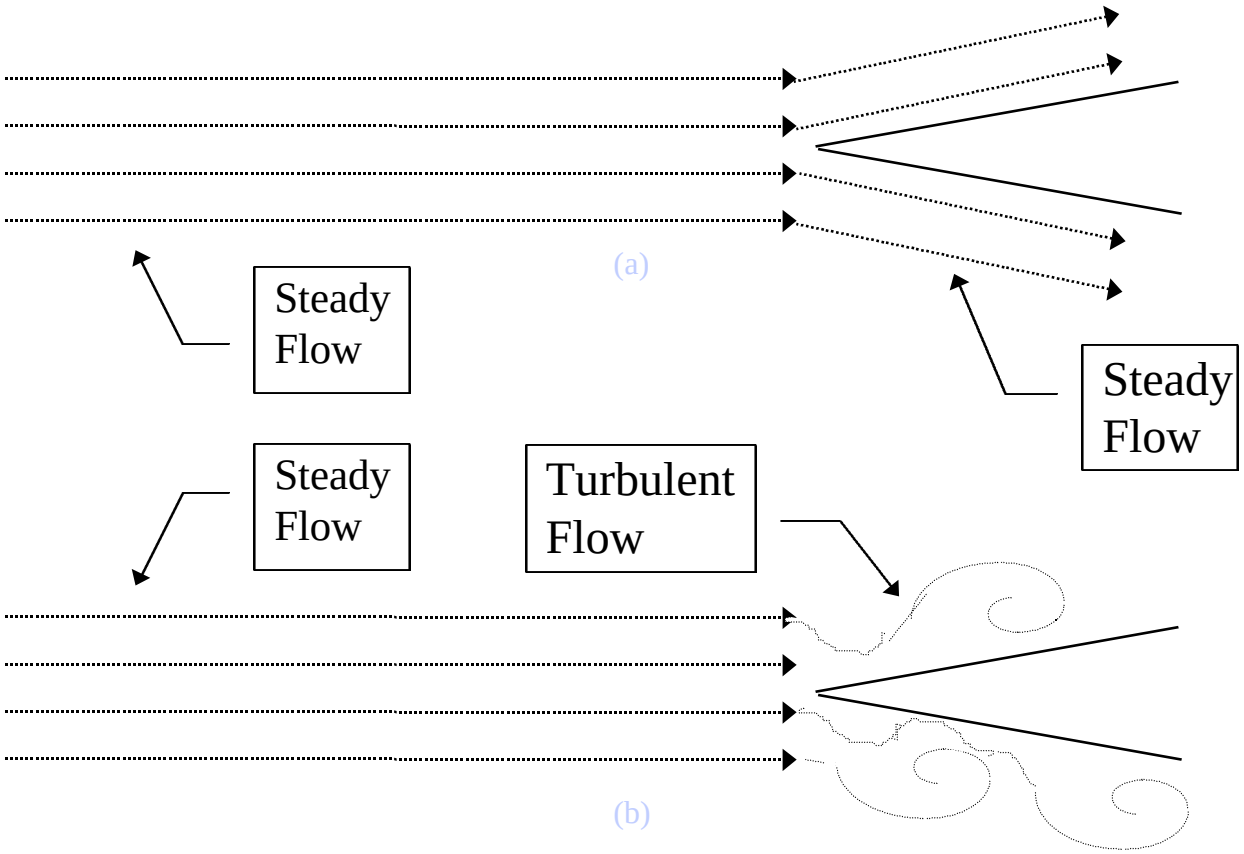
- Vibrating Lips
  - Similar to reeds, but the lip acts like the reed
  - Examples: Trumpet, tuba, French horn, baritone

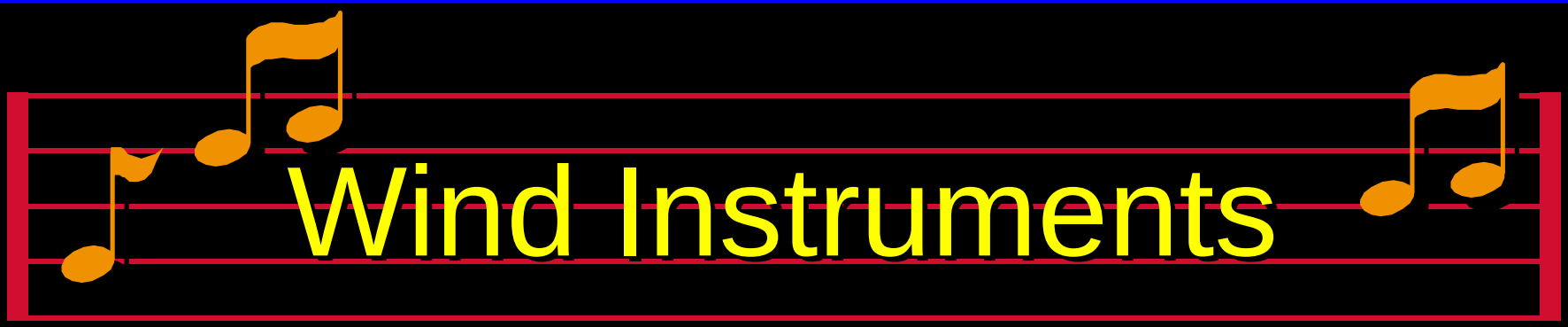


Wind Instruments

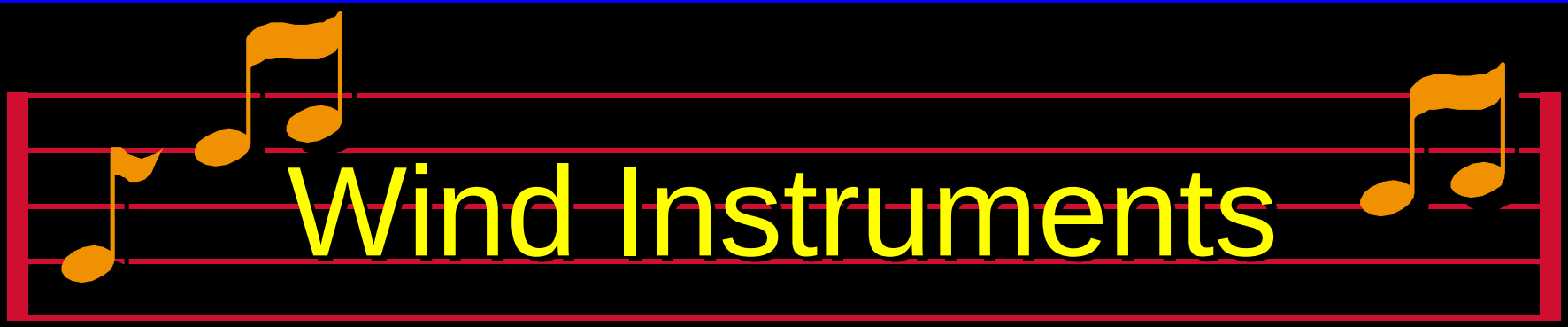
- Air Near the Opening
  - Steady flow vs. Turbulent Flow near a sharp edge
  - Turbulence cause pressure changes
  - Examples: flute, recorder, organ pipes

Wind Instruments

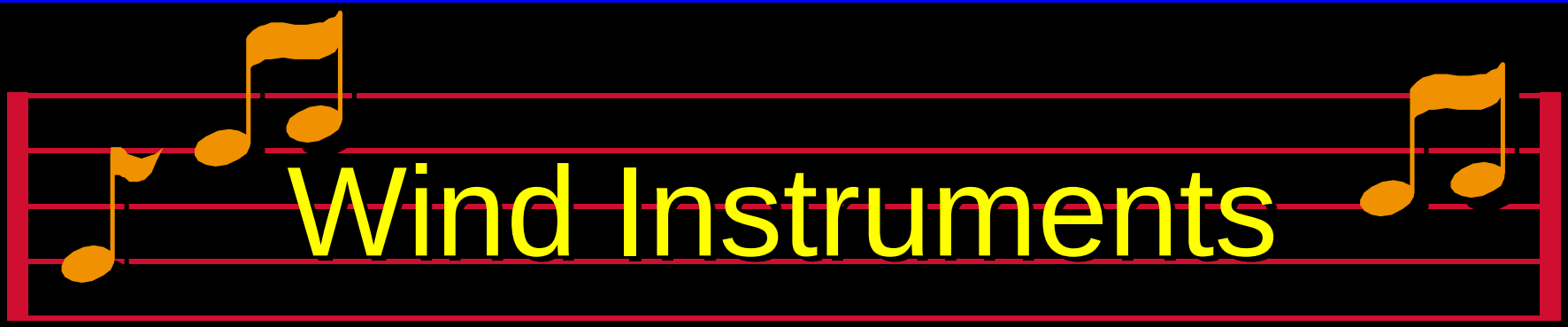




- Resonant Oscillator
  - Air Column Within the Tube that Constitutes the Body of the Instrument
  - Demo



- Sound Emitter
  - Hole in the Opposite End



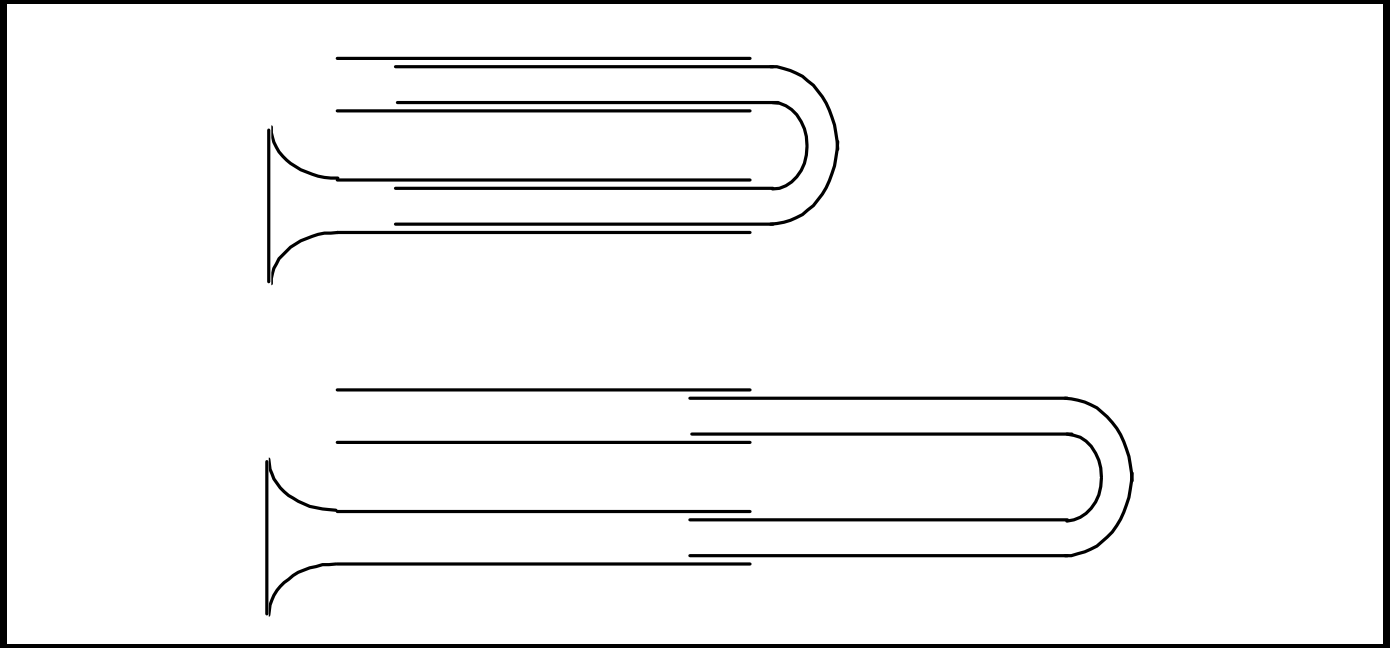
- Frequency Variation
  - Tubes of Different Length
  - Interlocking Pipes
  - System of Valves
  - Series of Holes

Wind Instruments

- Tubes of Different Length
  - Not convenient
  - Examples: Pipe Organ and Pan Pipes

Wind Instruments

Interlocking Pipes

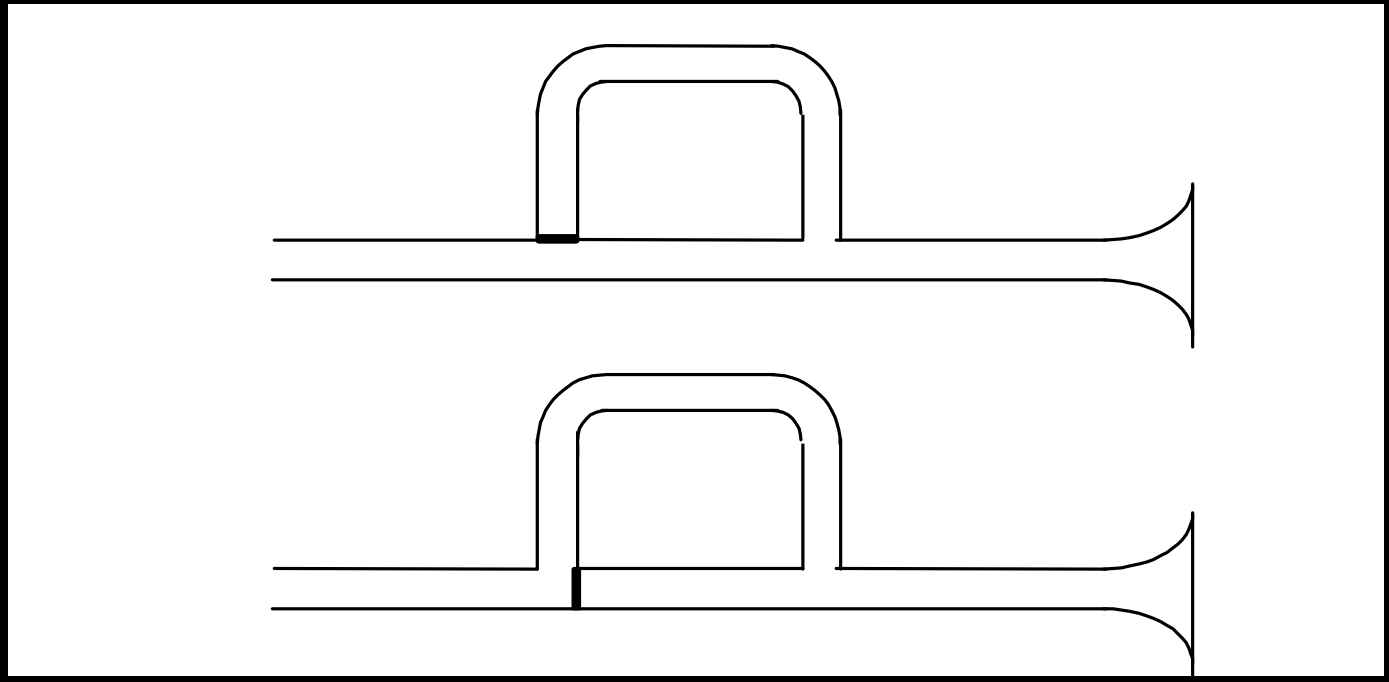


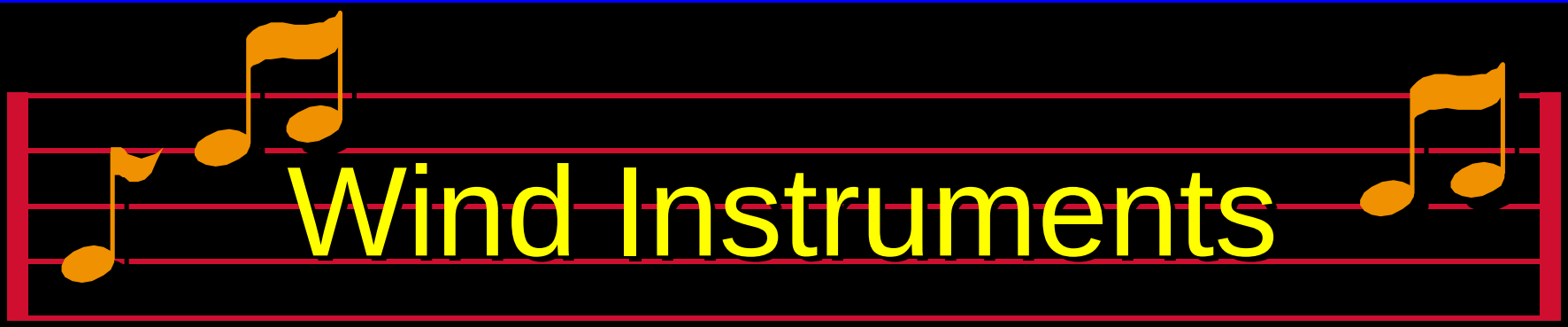
Wind Instruments

- Interlocking Pipes
  - Easy to get any pitch
  - Difficult to play because position must be exact
  - Example: Trombone

Wind Instruments

System of Valves

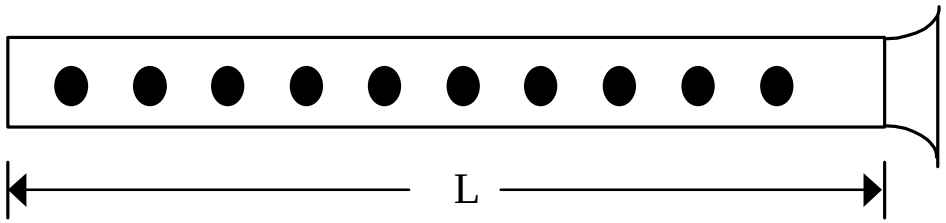




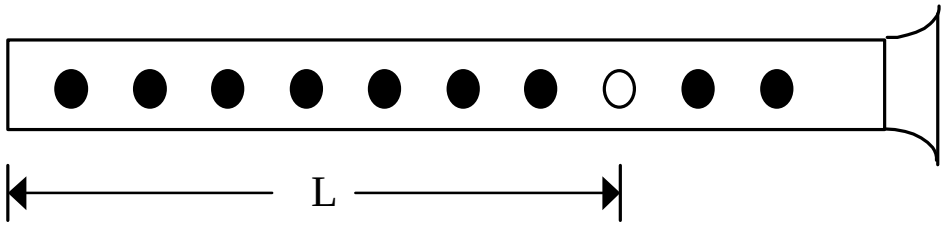
- System of Valves
  - Easy to play
  - Difficult to get pitch accurate for all notes (compromise)
  - Examples: Trumpet, French Horn, Baritone, Tuba

Wind Instruments

Series of Holes



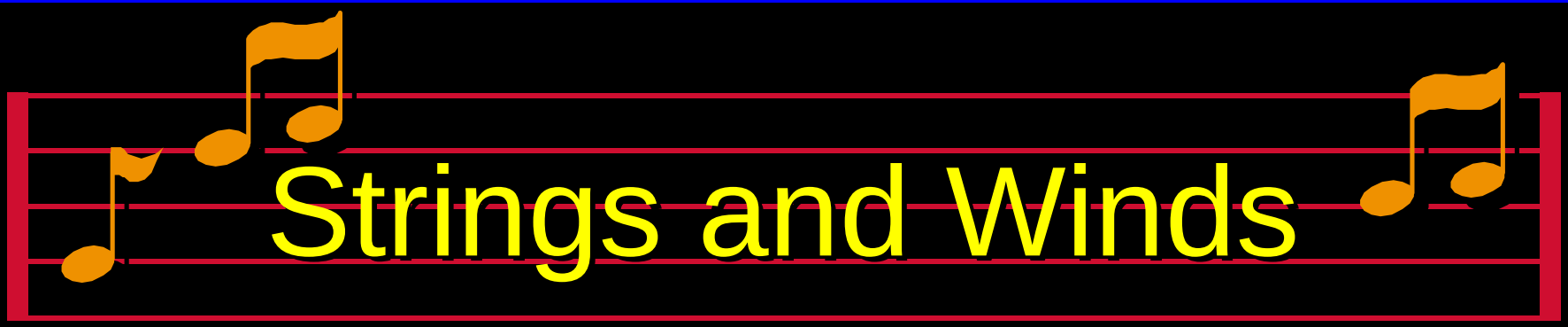
(a) All Holes Closed



(b) One Hole Open

Wind Instruments

- Series of Holes
  - Skill is required to cover the holes
  - Examples: clarinets, flutes, oboe, bassoon, recorder, and saxophones



Frequency vs. Length

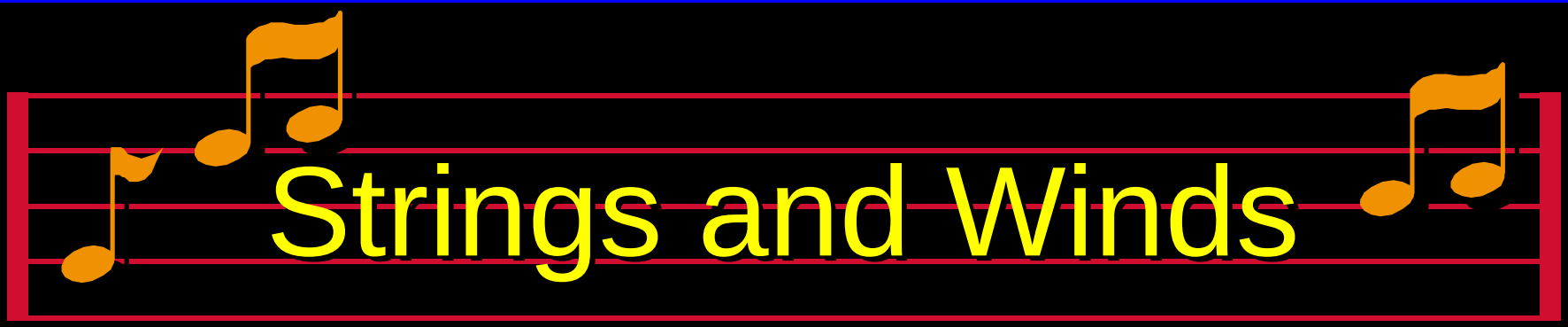
$$f_n = n(v/2L)$$

$$f_n = (2n-1)(v/4L)$$

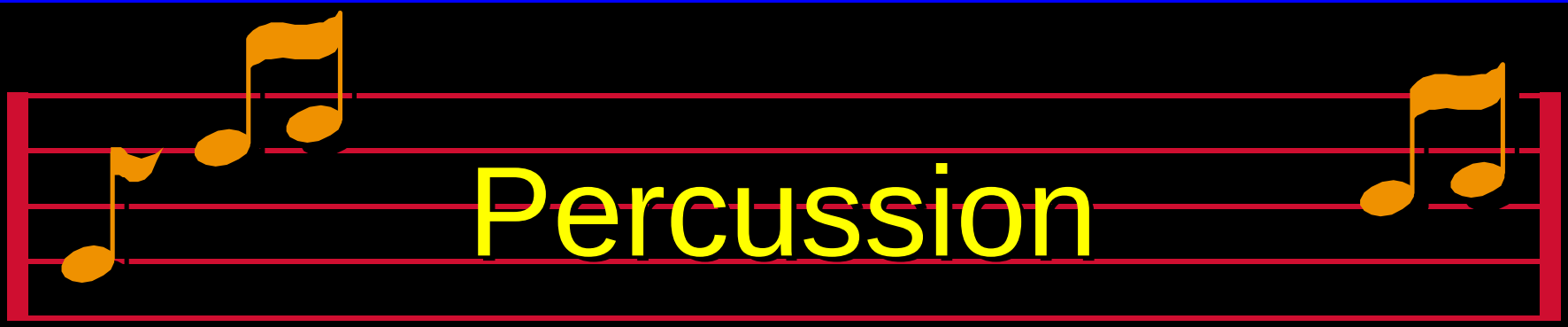
Strings and Winds

Frequency vs. Length

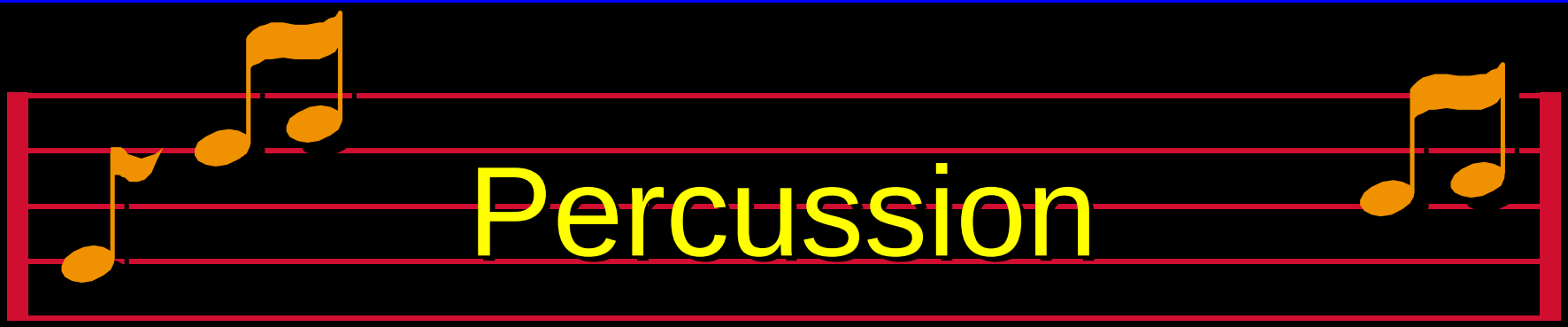
$$\frac{f_A}{f_B} = \frac{L_B}{L_A}$$



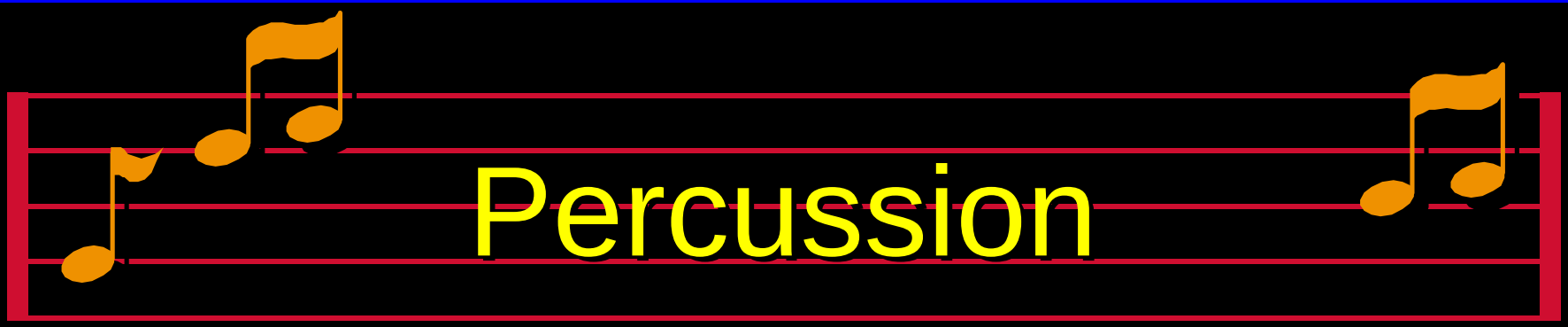
Look at examples on MI CD



- Energy Source
  - Arm motion
  - Finger motion
  - Foot motion

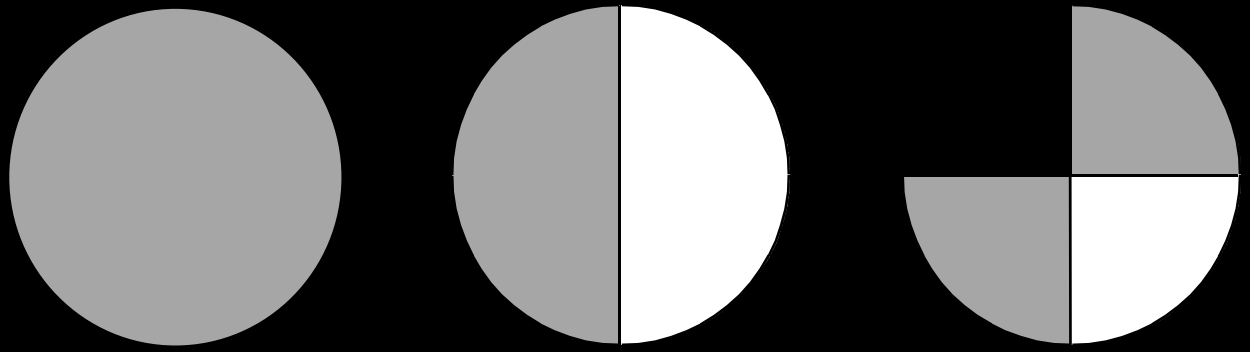


- Energy Connector
  - Sticks
  - Mallets
  - Hands
  - Fingers

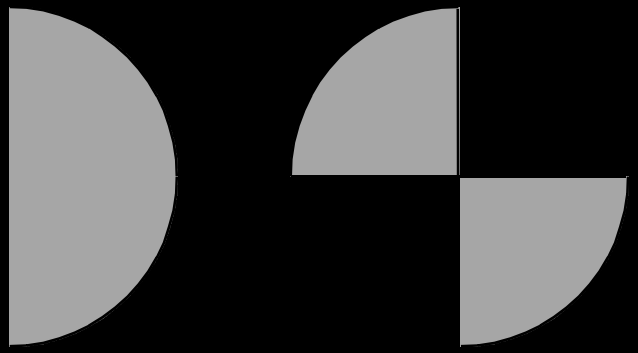


- Primary Oscillator
  - Two-Dimensional Surface
    - Drum Head
  - Three-Dimensional Surface
    - Cymbal, Gong, xylophone, chimes

Drum Head Radial Modes

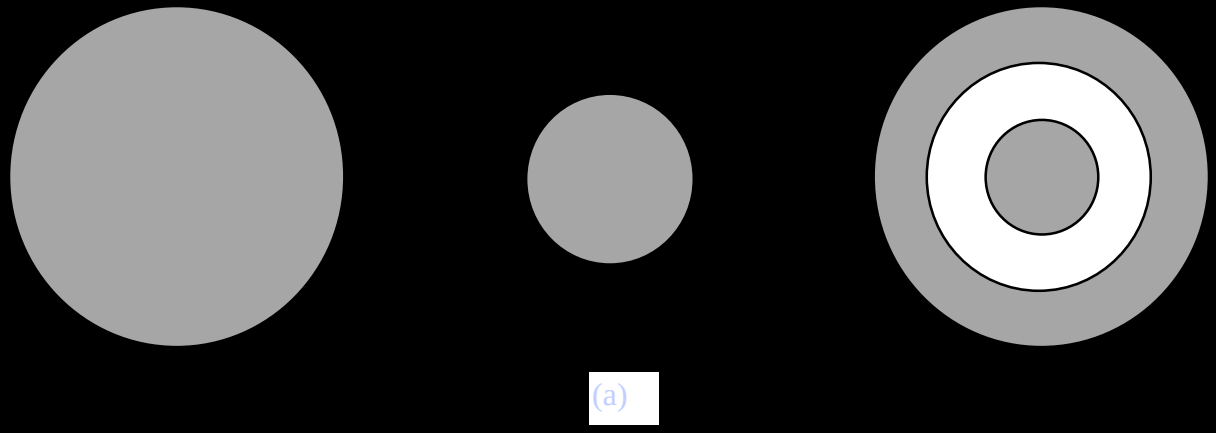


(a)

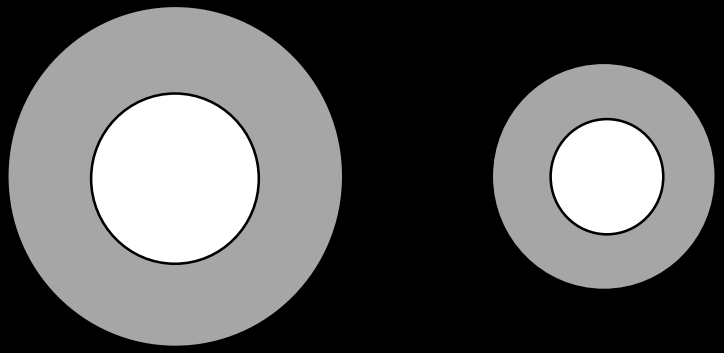


(b)

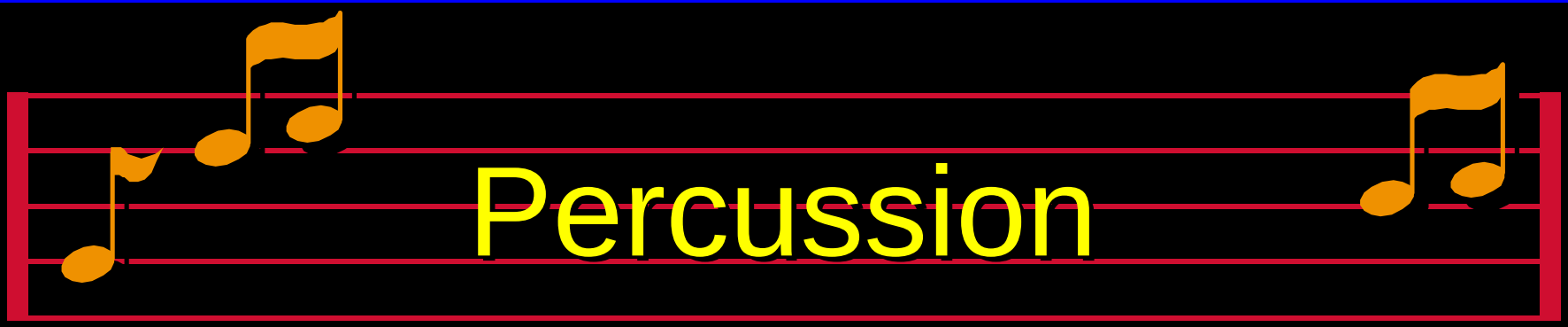
Drum Head Circular Modes



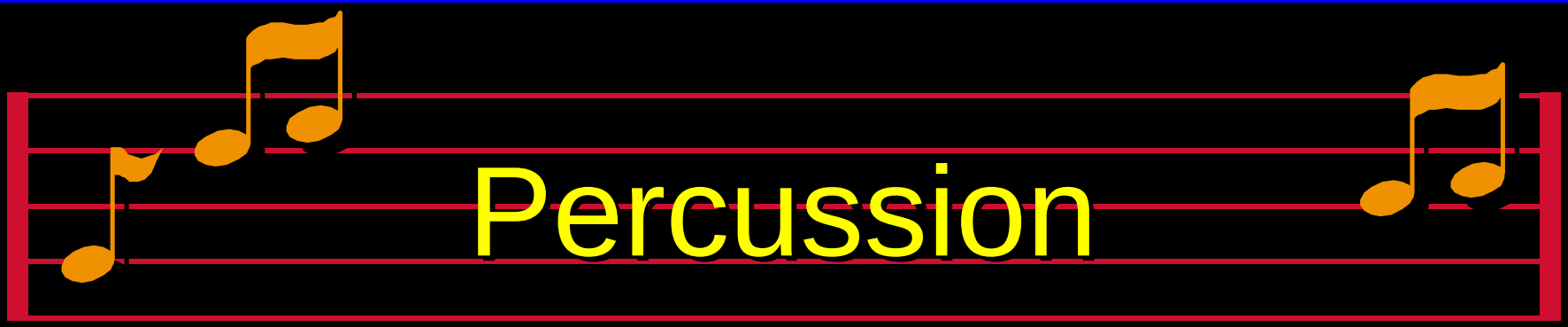
(a)



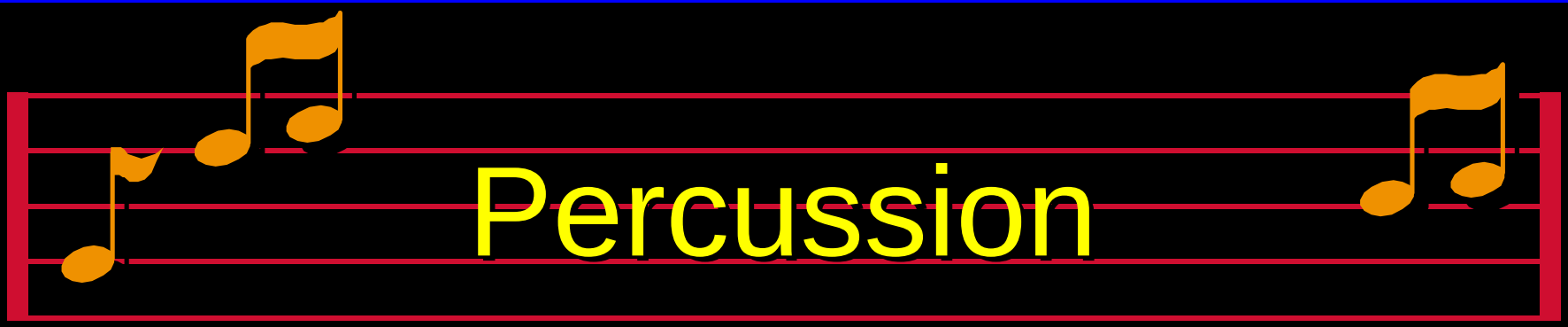
(b)



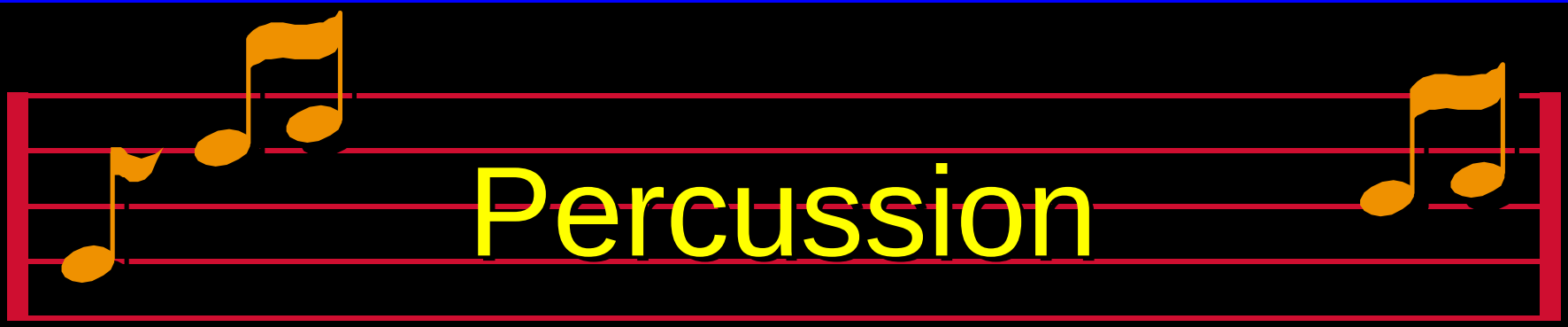
- Drum Frequencies
  - Not a harmonic series
  - No definite pitch
  - Noise
  - Role in music is rhythm not melody



Video Tape III-4

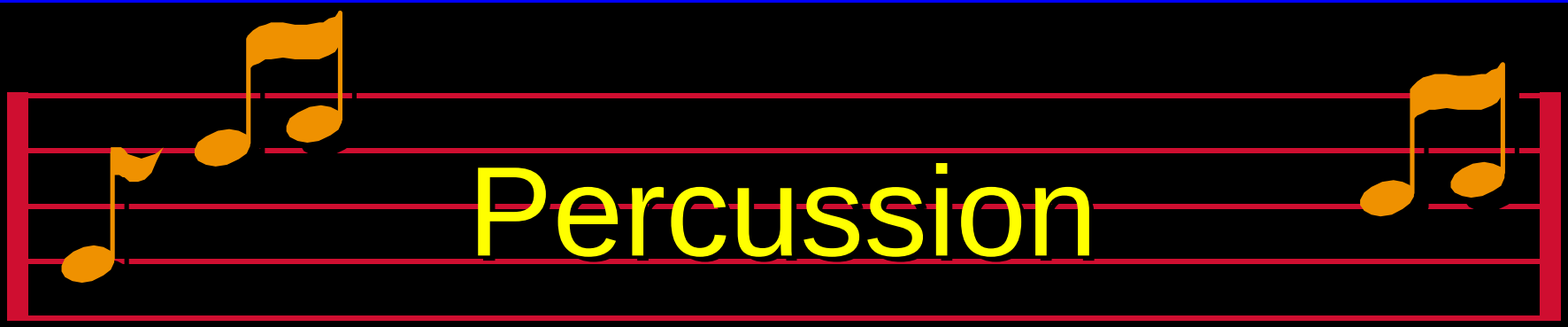


- Timbre
  - As with stringed instruments, timbre can be made to change depending on how the instrument is struck.

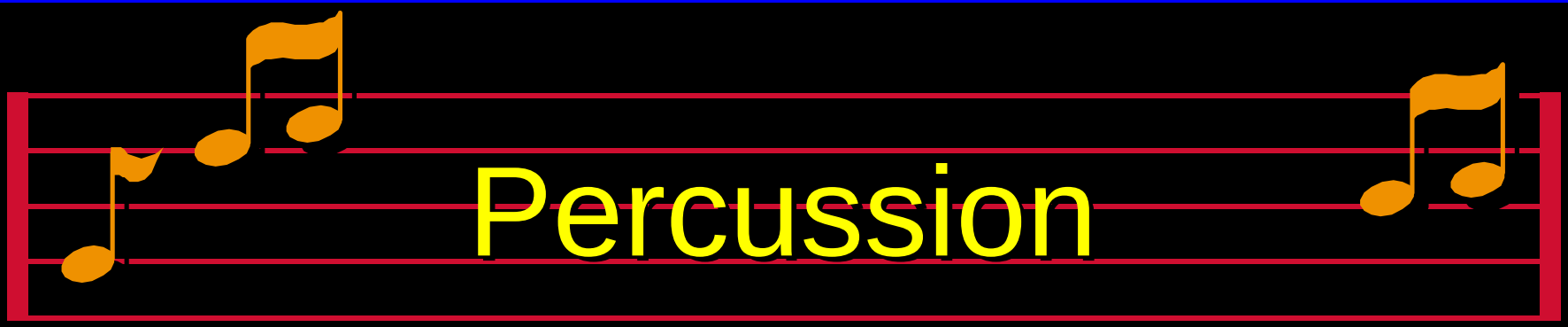


Percussion

- Resonant Oscillator
  - Wide variation that depends on the instrument
  - Examples:
    - Tympani
    - Chimes
    - Xylophone
    - Cymbals and Gongs.



- Sound emitter
  - Often is the Resonant Oscillator itself



Look at examples on MI CD