

**PHY 411-506 Computational Physics II**

**Chapter 11: Vibrations, Waves, and the Physics of Musical Instruments**

**Lecture 1**

*Wednesday March 26, 2008*

# Lecture Outline

|   |          |
|---|----------|
| <b>Music and Musical Instruments</b>          | <b>3</b> |
| <b>Plucking a String: Simulating a Guitar</b> | <b>5</b> |
| Guitar Acoustics . . . . .                    | 5        |
| Plucking a String . . . . .                   | 5        |

## Music and Musical Instruments

- The Human Ear detects vibrations mainly in air, but also transmitted through body
- The Human Brain interprets some sound sequences as Music
- Musical sounds are characterized by
  - ◇ Pitch
  - ◇ Rhythm
  - ◇ Dynamics
  - ◇ Timbre
  - ◇ Texture
- Musical sounds are produced by musical instruments
  - ◇ Human voice
  - ◇ Vibrations of strings (violin, guitar, piano, ...)
  - ◇ Vibrations of bars or rods (xylophone, chimes, clarinet reed, ...)
  - ◇ Vibrations of membranes (drums, banjo, ...)

- ◇ Vibrations of air in a tube (organ pipe, brass and woodwinds, ...)
- ◇ Vibrations of air in a closed container (drum, violin, guitar body, ...)
- Experience of music is affected
  - ◇ Auditorium Acoustics
- Music can also be created electronically
  - ◇ Synthesizers
  - ◇ Algorithmic Computer Music
    - Csound
    - SuperCollider

# Plucking a String: Simulating a Guitar

## Guitar Acoustics

- Good online guitar acoustics reference

## Plucking a String

- Guitar has 6 strings
- Pluck a string using finger nail or pick
  - ◇ Produces triangular standing wave obeying

$$\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2}$$

- ◇  $x$  measures length along string
- ◇  $y$  measures transverse displacement
- ◇  $c = \sqrt{T/\mu}$  is wave velocity
- ◇ String exerts square wave force on bridge

$$F_{\text{bridge}} = T \left. \frac{\partial y}{\partial x} \right|_{x_{\text{bridge}}}$$

- ◇ Vibrations transmitted to
  - Top plate (soundboard) – velocity of soundboard proportional to force – air pressure proportional to velocity of soundboard
  - Side ribs
  - Bottom plate (back)
  - Air in cavity
- ◇ High frequency sounds mostly produced by top plate
- ◇ Low frequency sounds produced also by air cavity and back
- Fourier transform gives frequency spectrum