PHY 411-506 Computational Physics II

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

Lecture 4

Wednesday April 2, 2008

LECTURE OUTLINE

Lecture Outline

Reed Instruments

Clarinet

Stick-Slip Motion of Bowed String

- Bows and Strings
- Player places bow on string and moves it at constant speed v_{bow} approximately perpendicular to string
- Bow exerts approximately constant normal force N on the string
- Repeat
  - ◇ Bow sticks to string and drags it in triangular shape

$$F_{\text{stick}} \leq \mu_{\text{s}} N$$

  - ◇ Maximum static friction is exceeded and string slips backward

$$F_{\text{slip}} = \mu_{\text{k}} N$$

Helmholtz Motion

- Helmholtz studied acoustics and physiology of hearing – invented Helmholtz Resonator
- Animation adding left and right moving waves

- Let c be the wave speed and L the length of the string
- Fundamental frequency of freely vibrating (plucked) string

$$f_1 = \frac{c}{2L}$$

- Place the bow at βL from the bridge
  - ◇ At $t = 0$ bow catches string and causes stick motion
  - ◇ Left and right moving waves travel to bridge and finger respectively
  - ◇ Left mover is reflected and inverted at bridge and returns at time

$$t_S = 2\beta L/c$$

    - ○ Suddenly increases F_{stick} and causes string to slip
  - ◇ Right mover is reflected and inverted from finger and returns at time

$$t_L = 2(1-\beta)L/c$$

  - ◇ Reflected left mover is further reflected and inverted at finger and returns to bow at time $t_S + t_L$
  - ◇ Reflected right mover is further reflected and inverted at bridge and returns to bow at time $t_L + t_S$

◇ At $t_S + t_L$ friction force is suddenly reduced and bow sticks

◇ Period of stick-slip motion of bow is

$$f_{\text{bow}} = \frac{1}{t_S + t_L} = f_1$$

Stick-slip in Geophysics

- Stick-slip Motion occurs along a geological fault, creating an earthquake

Vibrations of a Membrane

Normal Modes and Eigenvalues

- See Chapter 10, Lecture 11

Generation of Sound