Physics of Musical Sound

Class 19
Read Chapter 12
Sections 1-9
Lab Friday

Reed spectra

- The reed forms a valve that lets puffs of air through as it opens and closes an opening. Since the puffs are perfectly periodic they have a perfectly harmonic spectrum.
- The spectrum is not only harmonic but very rich in harmonics. Especially in the case of beating reeds, the abrupt starting and stopping of the air flow gives rise to many high frequency harmonic components.

Woodwinds (reed)

- Energy source
  - Low pressure air stream from lungs or bellows.
- Vibrator
  - Springy strip of metal or cane (reed) opens and closes opening letting air pulses into the instrument
- Resonator (cane reeds only)
  - Tube supports standing waves
  - Sets frequency of vibrator and couples to outside air

Free Reed Instruments

- Reed cut to fit closely in an opening. Air pressure is higher on one side of the opening causing air to want to flow through.
- Flowing air pushes on the reed, bending it aside and increasing the width of the opening. This increases the air flow.
- Eventually the air force cannot get large enough to push the reed further and the reed starts to close.
- As soon as the reed starts to close the air force falls and the reeds closes even faster. Eventually the reed comes to rest again and the cycle starts over.
- Pitch of note is controlled by properties of reed. Reed must have a very clearly determined resonant frequency, that is, it must have a very high Q.
- High Q reeds are made out of materials with very little internal friction, usually special springy alloys of copper. Such reeds are called hard reeds.

Reeds

- Reed is a thin, flexible bar clamped at one and and free to move at the other. It moves under the influence of air blown past it.
- Distinguish
  - Beating Reeds: reeds that move over an opening alternately opening and closing it, allowing air to move through or not to move through. Reed is almost always coupled to a resonating pipe through which the puffs of air flow.
    - Examples: clarinets, saxophones, oboes, bassoon, bagpipes
  - Free Reeds: reed moves freely within an opening never allowing the gap to close, still controls passage of air. Reed controls air directly without aid of a resonant pipe.
    - Examples: mouth organ, accordion, harmonium, regals, some organ stops

Free Reed Instruments

- Pitch of the reed is controlled by the length of the reed and by its thickness. Longer reeds are more massive and beat more slowly, thicker reeds are stiffer (as well as somewhat more massive) and beat faster.
- Weights are added to the tips of the lowest pitched reeds to bring the frequency down still further without excessive length.
- By controlling the width of the reed, the material of the reed, and how it fits in the opening the maker can alter the sound to some extent.
  - For example, making the reed fit more tightly in the opening makes the air pressure changes more abrupt and so produces a sound richer in high frequency harmonics, a brighter sound.

Beating Reed Instruments

- For sound to be controlled by tube, the reed must not have too firm an idea of the frequency at which it will vibrate.
- Want reed to able to vibrate well over a wide range of frequencies so that it must have a broad, low resonance. Thus a beating instrument reed must have a very low Q.
- Low Q reeds need to have a lot of internal friction and are made chiefly of cane (with some plastics starting to be used, at least for practice reeds). These low Q reeds are called soft reeds.
- Because the reed can operate over a very wide range of frequencies, the mode of vibration will be controlled by the tube and so we need to couple the tube strongly to the reed.

Beating Reed Instruments

- Beating reeds completely close the opening as they vibrate. The pressure changes at a beating reed are large but the amount of air that flows through is small. Thus reeds approximate closed ends of a tube.
- If we couple a beating reed to a cylindrical tube then it will sound as a half-closed tube.
  - Lowest frequency will be 1 octave lower than a completely open tube of the same length.
  - Sound will be lacking in even harmonics. This accounts for the characteristic hollow sound of the low range (the chalumeau range) of the clarinet family. (Reed effects take over higher.)
  - Great for low bass instruments eg. Octobass clarinet

Air Pressure Patterns w/ Reeds

- We saw that the flute family of instruments operated with a shape to the air pressure in the instrument column that corresponded to having a pressure node near the top of the instrument.
- That means that it is hard to get a large pressure change at the mouthpiece but easy to make air flow into and out of the pipe.
- Reed instruments operate in exactly the opposite situation. It is very hard to get much air to flow into the instrument but easy to make large pressure changes at the mouthpiece.
- We describe this difference using the idea of impedance. Impedance is a measure of how easy it is to get a wave to move upon a medium.

Beating Reed Instruments

- If we couple to a conical tube then the modes shift back to harmonic.
  - Same patterns as a cylindrical tube of same length open at both ends.
  - Thus oboes and flutes, same length, same pitch; clarinets sound octave lower.

Air Pressure Patterns w/ Reeds

- As saw with brass instruments, it is hard to make the air in a pipe move. It takes large pressure changes to force air into the instrument, and so we say that the reed has a high input impedance.
- In order to get a good coupling between the high impedance of the reed and the tube, there must be a high impedance at the mouth of the tube.
- This means that there must be an anti-node of pressure at the mouth of the tube.