Lab 12
Musical Instruments

Purpose:
Study the physical properties of different instruments. Students should attempt to understand some of the instruments on the basis of the principles they have learned in lecture and in previous labs. They are encouraged to study two or three instruments in detail. Most suitable are studies of the guitar and the trumpet or French horn. Relating the length of various woodwinds to the expected frequency of cylindrical or conical pipes is also beneficial.

Equipment:
We were able to acquire quite decent used instruments from our Music School. The instruments available in the lab at this time and the suggested corresponding investigations are listed below.

1. **Guitar.** What is the advantage of frets over unfretted instruments, for example the violin? Can you see a reason why guitarists put the finger between frets rather then on the frets? Measure the length of the string from nut to bridge. Calculate the required lengths of the vibrating string necessary to play tempered half-tone intervals and write the results in a table. Now carefully measure the fret positions and compare to the calculation. Why do the frets get closer and closer spaced? What musical intervals do the dots on the fingerboard mark? What is the fret spacing when you go up an octave compared to the first spacing near the nut?

2. **Violin**. Observe the Fourier spectrum of a bowed string. Observe the changes in the spectrum depending on the position of the bow along the string – if the string is bowed (or plucked) 1/4 of the length from the bridge are some partials missing – which? Why? If a magnetic pickup (guitar pickup) is available, observe the wave form of a bowed string and relate it to the expected saw-tooth motion. The pickup responds to the speed of motion of the string, not its position.

3. **Flute and Recorder**. Calculate the frequency when all finger holes are closed. Measure the frequency e.g. from the scope display, or with the Fourier analyzer. What tone of the musical scale does the frequency correspond to? To what tone does the instrument overblow?

4. **Clarinet, Oboe**. How do reeds work? Which of these two instruments is cylindrical or conical over most of its length? Relate frequency to length of the instrument.

5. **Brass instruments** (Slide Trombone, Trumpet, French Horn). At the mouth piece there is a large pressure change thus are any of these instruments open or closed pipes? Observe that over most of the length of the instrument the pipe is cylindrical, though curved and with a flared bell at the end. Extend a piece of twine along the instrument to determine the total length, then emasure the

length of the twine. Calculate the fundamental frequency. Blow a tone and measure the frequency. What number mode is this close to? Note that the mouth piece and the bell shift the resonance frequencies away from the simple cylindrical pipe. (It may help to give the student the relevant pages of a book like A. H. Benade ("Horns, Strings and Harmony", Dover 1992) or Fletcher and Thomas D. Rossing ("The Physics of Musical Instruments", Springer 2010). Valves on the trumpet or the French horn are used to add a length of additional tubing, and thus lower the pitch by a certain number of semi-tones. Compare the added length to the full length of the instrument to find by how many semitones the pitch is lowered. Why are 3 valves enough to play the complete scale in half-tone intervals ("chromatic scale")?

6. **Percussion Instruments**: the motion of a drum head, for example the timpani, is best observed with a strobe-light. One can also use a rubber membrane excited by a bass loudspeaker. The equipment can be made rather easily by stretching latex rubber sheet (rubber dam) over a short piece of large-diameter tubing (e.g. PVC drain pipe). Symmetric modes are obtained if the loudspeaker is centered under the membrane, asymmetric modes by displacing the loudspeaker. Instructors can model other percussion instruments with modest effort, e.g. a model vibraphone can be made by mounting a metal bar over a resonance pipe which a motor (or a student!) rapidly covers and uncovers to produce an intensity modulation.

7. **Voice**: use a Fourier analyzer to study formants of different vowels. Sing aah – ooh - eeh etc at the same pitch and compare spectra – what stays the same? What changes? Sing the same vowel at different pitches – what stays the same, what changes?