**Lab 10**
**Fourier Synthesis and Fourier Analysis**

Purpose:
Synthesis. Students should learn that any periodic oscillation (i.e. a complex tone) can be produced as a superposition of sine waves with frequencies that are multiples of the fundamental frequency of the oscillation, with suitably adjusted amplitudes and phase. They discover that changing phase between the Fourier components changes the wave shape (seen on the oscilloscope) but does not affect the audible tone. They further discover that the pitch of a tone depends on the fundamental frequency, even if the fundamental itself is absent (missing fundamental), i.e. superposition of 100 Hz,
150 Hz, 200 Hz, 250 Hz is by most people perceived as 50 Hz.
Analysis. Observe the Fourier spectrum of sine waves with various amplitudes and frequencies. Observe the spectrum of a square wave. Observe the spectrum of the human voice and compare different students' voices.

**Experiment Part I: Fourier Synthesis**
Equipment:
For more than two decades we used a commercial Fourier synthesizer (PASCO), but this equipment is no longer available and we recently changed to use of an Applet on our lab computers. Advantages are that software is available free of charge on the web, and that (contrary to the hardware synthesizer) the fundamental frequency is adjustable. We modified available freeware because for didactic simplicity in the course lectures we specify the components of the Fourier spectrum the amplitude and phase [$(a \cdot \sin(2\pi f + \phi)$] rather than amplitudes of sine and cosine.

Exercises:
Superposition of two sine waves (pure tones) of the same frequency – adjust phase and observe the wave shape and amplitude of the superposition. Can two pure tones completely cancel one another? Why does it not happen in an orchestra?
Build an approximate square wave by addition of sine waves (would the second harmonic be helpful?).
Add two, three, four harmonics and change the phase - does the wave shape change? Does the sound change?

**Experiment Part II: Fourier Analysis**

Equipment:

We use a Fourier analyzer Applet on our lab computers. The computer requires a sound card for external sound input.

The screen shows the wave form and the spectrum. The frequency range of the spectrum is adjustable, and so is the time scale of the waveform displayed.

Exercises:

To understand what the spectrum represents, analyze a single sine wave – change the frequency, change the amplitude. Note correspondence of spectrum to the amplitude and frequency set on the oscillator.

Fourier spectrum of square wave – what is the regularity in the measured amplitudes of the harmonics?

Fourier analysis of tuning fork, of voice and of musical instruments Compare two voices singing the "same" tone – shows that different voices have different spectra. Compare a voice and a musical instrument (same pitch) understand what "timbre" is. Have a male voice match the frequency of an A-tuning fork – what is the fundamental frequency? It often is NOT 440 Hz!