Possible Experiments for UIUC Physics P193POM/P406POM Acoustical Physics of Music/Musical Instruments Course(s)

n.b. **This is only a partial/incomplete list – just to get people thinking!!!**

I. General/Arbitrary Musical Instruments:

1. **Harmonic Analysis of Sounds from Any/All Musical Instruments:**
   - **Record musical sounds using microphone & 24-bit Marantz PMD-671 Digital Recorder, xfer *.wav file(s) to PC, analyze harmonic content of recorded sound using MatLab Wav_Analysis program.**
   - **Use microphone & HP 3562A Dynamic Signal Analyzer (interfaced to PC) to obtain harmonic content of sound from musical instrument. Obtain record of shape of waveform from Tektronix digital oscilloscope. Transfer DSA data from scope to PC via GPIB for offline analysis.**
   - **Use microphone & Tektronix digital oscilloscope to carry out harmonic analysis on scope (Fast Fourier Transform, or FFT), transfer data files from scope to PC for further use/additional analysis.**

2. **Mechanical vibrational analysis – measure/map out complex normal modes of vibration of musical instruments:**
   - **Use PC-based DAQ system(s) – function generator + lock-in amplifiers.**
   - **Use HP 3562A Dynamic Signal Analyzer – cross-correlation/FFT method.**
   - **Chladni Patterns**

3. **Investigate/Explore/Generate Fractal Music & Mathematics of Fractals**

II. Wind/Lip/Reed Instruments and Acoustic Resonators:

1. **Phase-Sensitive Measurements of Complex Input/Output Impedance, Z and Complex Sound Intensity I of Wind/Lip/Reed Instrument(s) using UIUC P498POM P/U Nano-mics, Lock-in Amplifiers, Piezo Transducer + Function Generator and PC-Based Lab-Windows/CVI DAQ PUsound4.prj Program as function of frequency and for various valve combinations/notes, and/or using different mutes, mouthpieces, other settings, etc.**

2. **Study/Investigate the Complex Acoustic Properties of Standing Wave Tube, Acoustic Resonators – e.g. Helmholtz Resonators, Arbitrarily-Shaped Glass Bottles, etc. as a Function of Frequency – Use e.g. Same Equipment as Above.**

3. **Study/Investigate the Complex Acoustic Properties of Loudspeaker Enclosures as a Function of Frequency, using Same Equipment as Above.**

III. Percussion Instruments:

1. **Phase-Sensitive Measurements of Complex Modal Vibrations of Percussion Instrument(s) – e.g. Drums using UIUC P498POM P/U Nano-mics, Lock-in Amplifiers, Piezo Transducer + Function Generator and PC-Based Lab-Windows/CVI DAQ Modal_Vibes.prj Program as function of frequency and for various modes of oscillation, drum head types, drum tension, temperature, bearing edge type, other settings, etc.**

2. **Study/Investigate the Harmonic Content and Decay Time(s) vs. Frequency of Percussion Instruments as a function of excitation method, drum head type, drum tension, other settings, etc.**

3. **Investigate/Measure the Modal Vibrations of Isohedral Drums.**

IV. Acoustic Stringed Instrument Experiments:

1. **Strings:**
   - **Use Tektronix digital oscilloscope + FFT Harmonic Analysis of signals from strings, study & compare e.g. Nylon vs Steel.**
   - **Measure/compare decay times of strings - steel vs. nylon - fundamental & harmonics.**
   - **Study attack & harmonic content of picking techniques, and/or different types, sizes, shapes, and/or thicknesses of picks.**

2. **Necks/Tuners/Nuts:**
   - **Use PC-based DAQ system to study & compare different necks, neck woods, fretboard woods, neck finishes, neck damping, FatHeads, nut materials, etc.**

3. **Bridges:**
   - **Study/compare different types bridges, bridge materials – how affects sound.**
   - **Measure intonation e.g. on acoustic guitar or e.g. mandolin. Compare w/ e.g. intonation electric guitar. Study vs. string gauge and string type.**
   - **Compare intonation of guitar with Buzz Feiten tuning system installed vs. one without it.**

4. **Bodies:**
   - **Studies of mechanical vibrational properties using PC-based DAQ system.**
   - **Study different kinds of wood/bracing/construction affect sound - measure frequency response, study/investigate resonances.**

5. **Acoustic Guitar Active Pickups/Controls:**
   - **Compare the performance of various piezo pickups vs. miking the guitar.**
   - **Design/build/measure properties of preamp for piezo pickup.**
   - **Study/measure the frequency response of piezo pickup and its preamp.**

V. Electronic Stringed Instrument Experiments:

1. **Strings:**
   - **Use Digital `Scope + FFT Harmonic Analysis of signals from strings, study different kinds/brands of strings - quality of intonation vs. brand, quality of intonation new vs. old strings.**
   - **Stand-alone setup to measure string tension - balanced tension for sets of strings vs. brand? Propagation speed constant vs. frequency?**
   - **Measure decay times of strings - study air damping and magnetic damping vs. string type/string brand.**
   - **Study attack & harmonic content of picking techniques, pick type.**

2. **Necks/Tuners/Nuts:**
   - **Use Digital `Scope + FFT Harmonic Anlysis to study & compare different necks, neck woods, fretboard woods, neck finishes, neck damping, FatHeads, nut materials, etc.**
   - **Studies of Mechanical Vibrational Properties of Guitar Neck/Headstock using PC-based LabWindows/CVI DAQ Sonic.prj program.**

3. **Bridges:**
   - **Bridge Intonation.**
   - **Comparison of Sustain vs. Type/Design/Construction of Bridges?**

4. **Bodies:**
   - **Studies of Body Properties using PC-based Laser Holography Techniques.**

5. **Pickups/Controls:**
   - **PC-based LabWindows/CVI DAQ – Pickup.prj to measure complex impedance of pickups, L, R, C, resonant peak, f_{res}, Q.**
   - **Use HP Dynamic Signal Analyzer to do same, more quickly, less detail…**
   - **Use Digital Scope + FFT Harmonic Analysis to study pickup response, pickup location, picking location, picking techniques, coupling of sound from amp back to guitar.**
   - **Active Pickups/Preamps.**
   - **Study Loading of Pickup by Volume & Tone Controls, using above DAQ…**
   - **Study Pickup Response for horizontal vs. vertical string oscillations.**
   - **Pickup Winding Machine & Wind/Rewind Pickups, Physical Properties of Wire used in Pickups.**
   - **New kinds of Wire for Pickups? (Ultra-Pure OFHC?).**
   - **New kinds of Pickups (e.g. Linear Hall Effect Sensors?? GMR Sensors??).**

VI. Amplifier-Related Experiments:

1. **Resistor Properties:**
   - **Audio AC properties of real resistors (carbon molded, carbon film, metal film, etc) with DC voltages across them, vs. frequency.**

2. **Blocking Capacitor Properties:**
   - **Audio AC complex impedance/tonal properties of real capacitors (oil-impregnated paper caps, oil-filled, polypropylene, polyester, mylar film, ceramic, silver mica caps) with DC voltages across them vs. frequency.**
   - **Use PC-based LabWindows/CVI DAQ – Capacitance.prj program.**
   - **Use Digital 'Scope in X-Y (Lissajous) mode, measure D-E hysteresis losses and phase shift vs. frequency. X-fer scope data to PC for analysis.**

3. **Electrolytic Capacitor Properties:**
   - **Charging Current/ESR vs. Time for Fixed DC Voltage.**
   - **Reforming of Electrolyte Layer vs. Shelf Time. Affects overall sound of amp?**

4. **Vacuum Diodes (Rectifier Tubes) & Thermionic Emission:**
   - **PC-based LabWindows/CVI DAQ – RectPar1.Prj**
   - **Electronics Work Bench/SPICE Simulations & Comparisons**

5. **Triode Tube Parameters:**
   - **PC-based LabWindows/CVI DAQ – TrioPar5.Prj**
   - **Electronics Work Bench/SPICE Simulations & Comparisons**

6. **Power Tube Parameters:**
   - **PC-based LabWindows/CVI DAQ – PowerPar1.Prj**
   - **Electronics Work Bench/SPICE Simulations & Comparisons**

7. **Triode Voltage Amplifier:**
   - **PC-based LabWindows/CVI DAQ – TrioAmp1.Prj**
   - **Electronics Work Bench/SPICE Simulations & Comparisons**

8. **Power Transformers, Amplifer Power Supplies:**
   - **Various Classic Power Transformer Module(s).**
   - **Use a variac to vary AC line voltage to amp, record sounds from amp using digital recorder as function of variac's AC line voltage and analyze using MatLab Wav_Analysis software.**

9. **Rectifier Tubes:**
   - **Measure Transient Response & "Voicing" of S-E Class A & P-P Class A/Class AB Amps to Different Rectifier Tubes & Solid-State Rectifiers - e.g. 5Y3, 5V4, 5U4, 5AR4/GZ-34 vs. SS Rect.**

10. Tone Controls:

- **Various Classic Tone Control Modules + PC-based LabWindows/CVI DAQ**
- **Electronics Work Bench/SPICE Simulations.**
- **Measurements of EQ response with actual Amps. Compare w/ Simulations.**

11. Phase Inverters:

- **Various Classic Phase Inverter Modules + PC-based LabWindows/CVI DAQ**

12. Output Transformers:

- **Measurement of Transformer Properties - `Scope + LCR Meter, Function Generator + DMM**
- **PC-based LabWindows/CVI DAQ**

13. Single-Ended Class A Tube Amplifiers:

- **Measure Operating Voltages vs. Variac AC Line Voltage.**

14. Push-Pull Class A/Class AB Tube Amplifiers:

- **Measure Operating Voltages vs. Variac AC Line Voltage.**

15. Speaker Properties & Speaker Enclosures:

- **Comparison of Loudspeaker Properties: Impedance vs. Frequency**
- **Measurement of Loudspeaker's Thiele-Small Parameters.**
- **Comparison of Open-Back vs. Closed Back Cabinets.**
- **Design Loudspeaker Enclosure(s) e.g. Using Bass-Box Pro Software, Then Build Loudspeaker Enclosure, Measure Acoustic Properties as a Function of Frequency and Compare to Theoretical Predictions.**
- **Design 2-Way/3-Way Cross-Over Networks e.g. Using Cross-Over Pro Software, Then Build Cross-Over and Compare to Theoretical Predictions.**

VII. FX-Related Experiments:

1. Distortion FX Boxes:

- **PC-based LabWindows CVI Simulations of Distortion/Non-Linear Response**
- **LabWindows/CVI Arbitrary Waveform Generator DAQ sytem**
- **Electronics Work Bench/SPICE Circuit Simulations**
- **Build simple distortion box circuits.**
- **Comparison of IC Op-Amp Loading Characteristics**

2. Spring Reverb Tanks:

- **Pulse Generator + RVB Tank + `Scope-based Experiment**

3. Tape Echo/Dimension-IV FX:

- **Study/Measure Echoplex, WEM CopyCat and/or Dimension-IV Performance?**

4. **Digital Delay/Echo FX:**
   - **Build Circuits using e.g. Panasonic Bucket-Brigade Charge-Coupled IC's**

5. **Vibrato/Chorus/Flanging FX:**
6. **Tremelo FX:**
7. **Wah-Wah FX:**
8. **Compressors/Expanders/Companders:**
9. **Rotary (Leslie) Speaker/Doppler FX:**
10. **N-Band Equalizers & n-th Order Filters (Bessel, Butterworth, Tschebychev)**
11. **Harmonizer FX:**

12. **Chaotic/Fractal Music Audio FX :**
    - **Chua's Circuit**

13. **Digital Signal Processors (DSP's):**
    - **Non-Linear Response Modeling/Distortion FX**
    - **Digital Delay/Echo FX**
    - **Vibrato/Chorus/Flanging FX**
    - **Tremelo (Amplitude Modulation)**
    - **Wah-Wah FX**
    - **Compressors/Expanders/Companders**
    - **Rotary (Leslie) Speaker/Doppler FX - big fan blades**
    - **Harmonizer FX**

14. **E-Bow/Sustainer Studies:**
    - **Use/Study Effect of E-Bow/Sustainer on regular electric guitars, lap steels..**
    - **Use/Study Effect of E-Bow/Sustainer e.g. on musical saw?**

VIII. Whole-System Experiments:

1. **Frequency Response, Phase-Shift, Tone-Control EQ, Distortion Properties of Favorite/Classic Amplifiers, using Favorite/Classic Electric Guitars.**

2. **Study Acoustical Coupling of Amp Back to Electric Guitar - Nature of Infinite Sustain/Feedback - Coupling via Fundamental and 2^{nd} & 3^{rd} Harmonics. Phasing Issues.**

3. **Real-Time (?) Spice Simulations of Classic Tube Amps:**
   - **Play Guitar → PC DAQ → Spice Amp Simulation → PC DAQ → Ref Mon.**

IX. Human Hearing Experiments – Psycho-Acoustics:

1. **Frequency Response of Human Ear:**
   - **Measure/Map Out w/ Function Generator + Speaker - how to quantify?**

2. **Phase Shift Sensitivity of Human Ear:**
   - **PC-based LabWindows/CVI DAQ - two arbitrary waveform generators driving stereo system, or headphones.**

3. **Investigation(s) of Consonance & Dissonance:**
   - **Use 2 function generators, several oscilloscopes, 4-channel audio-mixer, loudspeakers to investigate consonance/dissonance – sine waves, triangle & square waves.**
   - **Record consonant/dissonant signals/sounds & then analyze using MatLab Wav_Analysis software.**

X. Room/Auditorium Acoustics:

1. **Measure Acoustical Resonance Properties of Room/Auditorium as function of frequency at several locations. Use e.g. White Noise FG, Power Amp & PA Speaker, Reference Mic and HP Dynamic Signal Analyzer.**

2. **Measure T-30/T-60 Reverberation Time(s) of Room/Auditorium as function of frequency. Use Same Equipment as Above.**

XI. Ultra-Sound Experiments:

1. **Investigate the Phenomenon of Sonoluminescence/Standing Ultra-Sound Waves in Water.**

2. **Build An Ultrasound Transducer Array, use Non-Linear Mixing Techniques to "Beam" a Narrow-Focus Audio Signal.**