Homework 14

Due Tuesday, April 2^{nd} in class

Readings we have done so far and topics in each book that connect to the lectures and homework:

From Sundials to Atomic Clocks: Chapters 5-11.

- **Resonance:** If a system with a natural frequency f_0 is stimulated by a driving force with frequency f, then the system will have a large amplitude response when $f \approx f_0$.
- **Quality Factor Q:** How many oscillation cycles until the motion has a small fraction of its initial energy.
- **Quality Factor Q:** The spread of the frequencies on the resonance curve.
- Atoms and their excitations: electrons transition between allowed energy states.
- Energy of the emitted or absorbed photon is given by the transition energy of the electron in the atom. According to Planck: $E_\gamma = h \cdot f$, so the electron's ΔE goves the photon frequency.
- Moving atoms shift their emission/absorption frequencies due to the Doppler Effect.
  So, cooling atoms down reduces the spread in emission/absorption frequencies.
- Solar Time, Sidereal Time, Uniform Time Standards, International Time Standards.
- Leap Years, Leap Seconds, and other adjustments to keep calendars useful.
- (**not on the exam**) Details of various atomic clocks and radio time signals.
- (**not on this exam.**) Additive and Multiplicative Noise.

The Order of Time: Chapters 6-8.

- The world is made of events, not things. We should talk of "becoming", not ''being".
- "We describe the world as it happens, not as it is."
- The inadequacy of the grammar of our languages, as they were developed under various ideas about time that we now know are misconceptions.
- "Presentism": only your present moment is real, and only for you,
- "Eternalism": all moments in space-time have equal existence and reality, we just experience a set of them in a particular order.

A Brief History of the Philosophy of Time: Chapter 2.

- Locke: the empiricist view of time as coming entirely from experience.
- Kant: the idealist view that time is how we order our experiences as they happen.
- (**not on this exam**) Insights from the psycho-physics of time perception experiments.

Lessons from labs:

- How to read time and voltage on an oscilloscope. Using an oscilloscope to measure:
  - the amplitude and frequency of oscillations,
  - the FWHM of the resonance curve of an LC oscillator,
  - the RC time constant from a decay curve,
  - the frequency of an electronic clock wave pattern.
- Measuring a sample to predict the average and uncertainty of a population (M&Ms).

Physics we relied on to understand different types of clocks:

- Description of motion in terms of position, velocity, acceleration, and forces.
  Electrical analogy to charge, current, ...
- Damped motion and what the time constant will depend on (inertia and friction).
- The process of resonance; exciting the resonance as how we keep oscillators oscillating.
- Some of the atomic behaviors that modern clocks rely on.
- The inherent uncertainties of quantum phenomena.

Concepts and Mathematics of Uncertainty:

- Accuracy *vs.* Precision (Stability).
- Finding and using averages and standard deviations.
- The logic of taking larger samples to increase accuracy and to increase precision.
- The usefulness of high-Q systems for accuracy & precision.
- Distinguishing between *systematic* and *statistical* uncertainty.
- (**<u>not</u> on <u>this</u> exam.**) Oscillation phase and Allan Variance.

Thought questions:

1. Find the averages and standard deviations of these two measurement sets.
   Could they be measuring the same thing? $\{3, 3, 4, 4, 6\}$ & $\{5, 5, 5, 6, 6\}$.
2. If the atoms in an atomic clock warm up, why is the clock less accurate and less precise?
3. Be prepared to plot some frequency data and to find Q for that resonance.
4. How might Kant have adapted his idealist view of time with what we have since learned about the subjectivity of simultaneity?
5. Is a "world of events, not things" incompatible with our sense of past, present, and future?