

Intro:

*This week we begin to study the phenomenon of **resonance**: In driven, lightly damped systems the amplitude depends on the driving frequency and can grow quite large. We will see that oscillating systems driven at resonance can yield a breakdown of the system (for example the simple mass-on-a-spring and the Tacoma Narrows Bridge - video on Friday!!). At resonance such a system cannot dissipate all the energy that it gains from the driving force. In nature, driven oscillating systems frequently interact with their environment, dissipating energy through the production of waves - thus removing the destructive extra energy.*

On Monday we will start studying transverse waves living in one dimension (i.e. on a string).

Due Monday, February 9**Reading:**

- Wednesday: Kleppner and Kolenkow 10.3 (pg 421-432) on e-Reserves
- Friday: Kleppner and Kolenkow 10.3
- Monday: HRW 16.1 - 16.6, and pages 425 - 6
- For next Wednesday: 16.7 - 16.13 (we may not discuss phasors...)

Physics Topics:

- Oscillators with light damping
- Q
- Resonance

Math Topics:

- Solutions to a driven, damped oscillator

Problems:

From material in classes through Friday, February 6.

- (1) HRW 15.50 In your solution include a derivation of the equation of motion.
- (2) Give an example of a resonant system that we haven't mentioned in class (or on this Guide).
- (3) On top of the 279 m high Citicorp Center in NYC there is a huge damped mass-on-a-spring system on the 63rd floor.¹ It is designed to oscillate at the same frequency as the building itself.
 - (a) Why?
 - (b) During high winds, the 3.73×10^5 kg block of concrete completes one oscillation every 6.25 s. In 10 cycles the amplitude of oscillation is reduced from the maximum of 1.4 m to 0.80 m. Find the damping coefficient b .
- (4) *Look, Ma, a phase shift!* Using a pair of rubber bands and a mug (or other suitable mass) build a lightly damped oscillator.
 - (a) Determine the natural frequency of your oscillator.

¹The system cost \$ 1.5 million and is estimated to have saved \$ 3.5-4 million in 2,800 tonnes of structural steel which would have been required to stiffen the structure.

- (b) Bounce your mug and observe the phase when you drive it below the natural frequency, at the natural frequency, and above the natural frequency. Make a sketch of δ versus driving frequency ω for your system.
- (5) (a.) Find the resonant angular frequency from the expression for the amplitude. (b.) If you look at the resonance curves on pages 425-428 in K & K they are all centered on ω_0 , the *natural* angular frequency. Hmm! Explain this apparent discrepancy. Hint: For lightly damped systems...
- (6) A grandfather clock uses a pendulum 80 cm long to keep time. The clock is driven by a 2 kg weight that falls 70 cm every day. (Someone must wind the clock and lift this mass once a day.) The amplitude of the pendulum swing is 0.1 radians or about 6 degrees. The pendulum has a mass of 150 g. What is the Q of the clock?
- (7) Several years ago a student built a Foucault pendulum for the science building. Although some difficulties with the mount prevented it from "Foucaulting" (rotating the plane of oscillation), it's oscillations had impressive longevity. The 18 m pendulum took roughly 4 hours to come to rest. What was the Q for this pendulum? Based on your experience in the g lab, estimate the amplitudes of oscillation at the beginning and end of the 4 hour time interval.

Lab:

Resonance in a mechanical system continued - the resonance curve, Q , and comparing angular frequencies.

A look ahead...

Next week we turn to more on waves and sound. To look ahead see HRW Chapters 16 and 17.