A Summary of ES.255 Class 3, Feb 27, 2006

We did was some brainstorming on all three aspects, modeling, gate oscillation measurement, and rope oscillation measurement. The blackboard as it was at the end of class is shown in Fig. 1. I apologize if I did not give specific credit where it is due; if such occurs it is because I am reconstructing the conversation from memory.

Philippe observes that if this work shows the possibility that the oscillating rope can couple energy into the carabiner gate then he will quit climbing. Dave C says there may be other alternatives, for instance increasing the open gate strength of carabiners or educating climbers about the situations that lead to coupling.

Existing Data from the Literature:

There is some data from drop tests available in the literature. It would be handy to eyeball the data and compare it to the modeling results.

Modeling:

So far, Dave C had only been thinking about the frequency at which resonance occurs; Dany suggests that the carabiner gate damping might produce a lower Q value and thus extend the range of frequencies over which coupling is significant. A model ought to include info on resonant frequency, Q, and the number of cycles during which a significant amount of energy can be transmitted from the rope to the carabiner gate. Including the damping suggests that carabiners that get dirty or corroded (& thus better damped) might be more prone to chattering open.

One expects that if this coupling is to cause problems, then it must occur at about the point where the carabiner gate locks up under load.

There are two parts of the carabiner gate chatter cycle. In one part, the oscillation is governed by the spring and the gate inertia; in the other, the gate impacts the carabiner body and rebounds. How these two spring parts combine into one "frequency" is not clear.

Dave C says he expects carabiner frequencies on the order of a 10th of a second to a 60th of a second, based on having observed high speed video & done some spread sheet estimates.

Rope Oscillation Measurement:

Rod suggests use of piezos to measure oscillation, but is not sure how to incorporate them into a rope. They are easy to salvage from headphone speakers or perhaps keyboards. Requires preamp and amplifier to boost 10 mV signals.

High speed video? How high does the speed need to be?

It will be important to be able to control the conditions, perhaps hard for drop situation.

Tension measurement: If doing drop tests, it would be nice to measure tension vs. time.

The tension in the rope can be measured with a load cell. The change in tension due to the rope vibration is so small compared to the tension in the rope that the vibration is probably not measurable from the tension data.

For a static test (like a guitar string, not like a drop), the tension can be controlled by tying known weights to the bottom of a suspended rope.

Carabiner Gate Oscillation Measurement:

Piezzos might work well here.

Perhaps wiring up an ohmic contact (switch or variable resistance) between the carabiner body and the gate to detect chatter.

Perhaps glue accelerometer to the carabiner during a drop to measure oscillations of the carabiner. High speed video might be grand too.

Perhaps drive a carabiner with a speaker coil. Allows frequency sweeping.
Perhaps drive the carabiner with a stepper motor or other motor.

Another idea would be to use faraday's law & eddy currents to determine whether the gate is open or not. Capacitive sensing might work too. Doing so might make it possible to not mount the measurement device on the carabiner.

Quick Low Speed Video of Carabiner Gate Opening:

We took 60 frame/sec video footage of carabiners being thwacked against the table. In most of the footage, we could identify a single frame in which the carabiner gate is open (Fig. 2). We conclude that the frequency of gate oscillation is a little higher than 60 Hz. One implication is that we'll need a higher frame rate to actually measure opening times and to see when/whether gates are open.
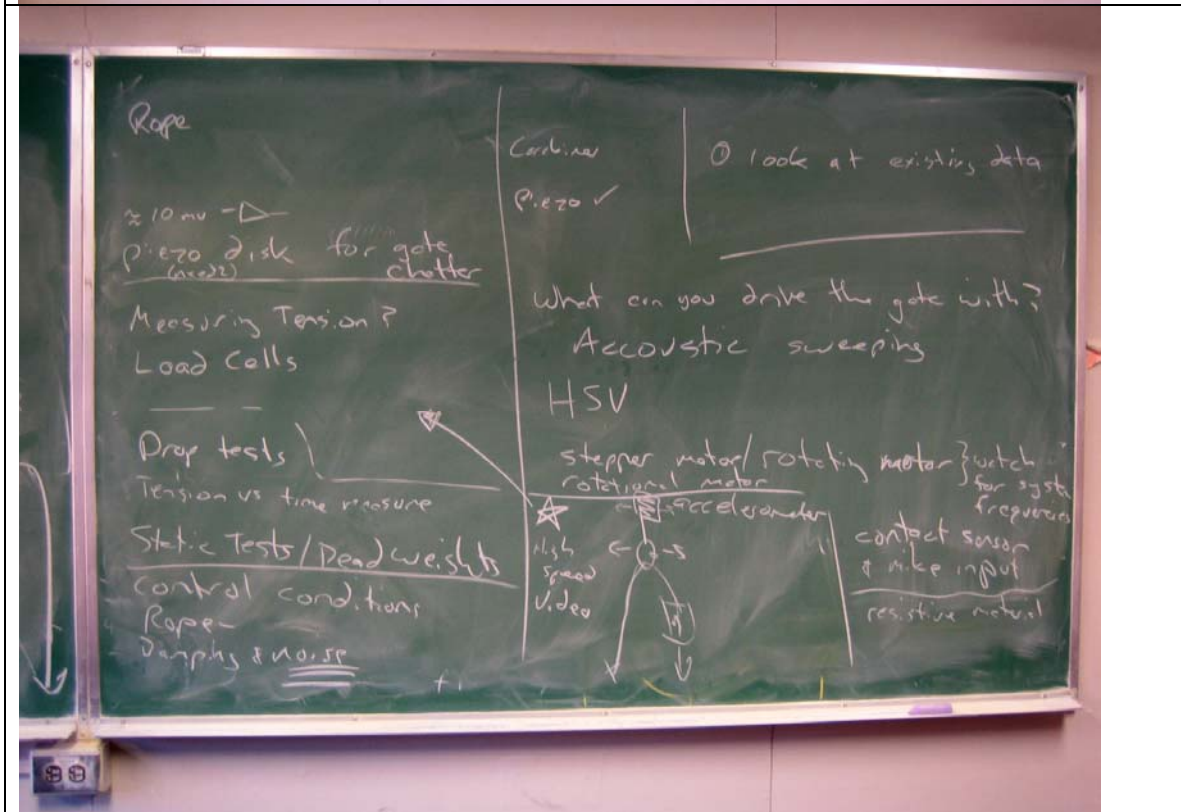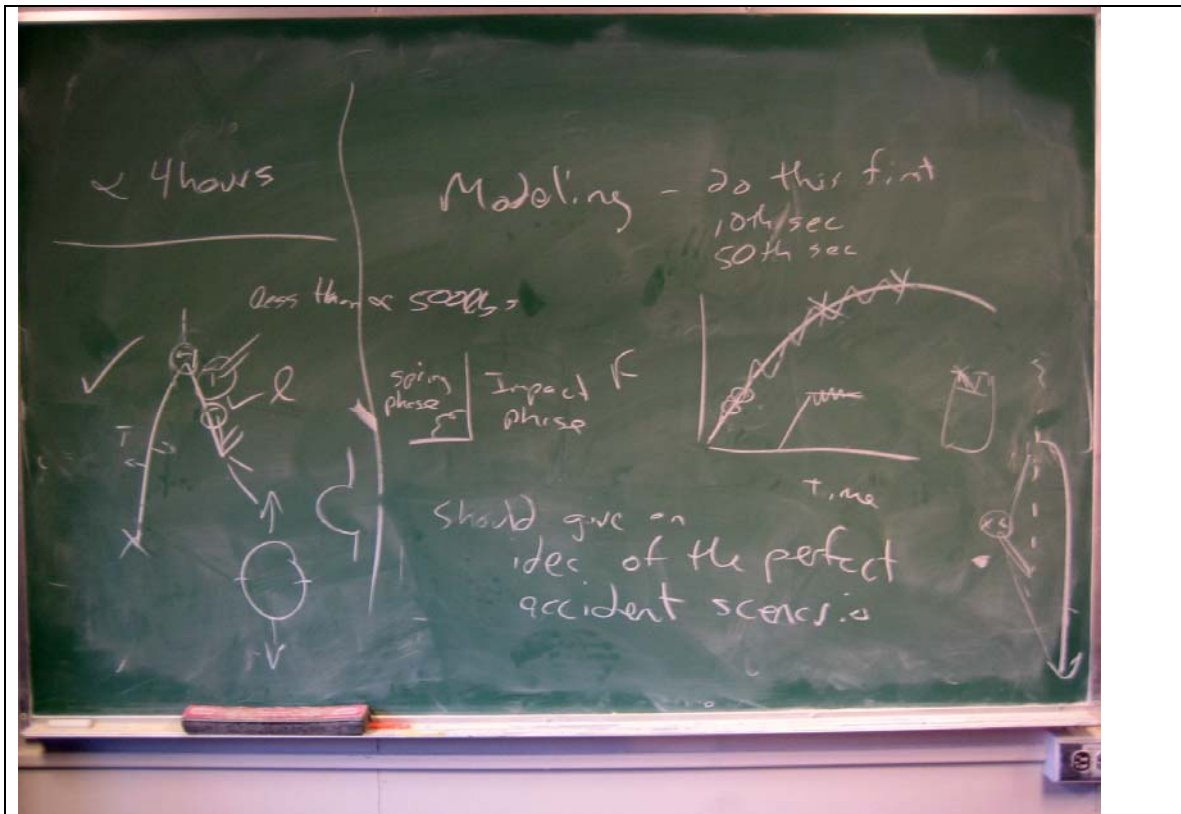
Figure 1 The blackboard at the end of class, Feb 27, 2006

Figure 2 Video frame with carabiner gate open

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