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Listening to Free Fall with the MacRecorder

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Here is a method of analyzing a classic free-fall demonstration[1] using current desktop computer technology.[2] You will need string, lead fishing weights from a local hardware store, a Macintosh computer, and a MacRecorder, or a comparable audio digitizer for the Macintosh. The MacRecorder digitizes eight bits of sound at a maximum rate of 22 kHz, and can play back recorded sounds, show sounds graphically, and analyze them in several modes. For the recordings shown here, time intervals were taken directly from the sound "pictures," which are similar to digital oscilloscope frames. SoundEdit, a software package that comes with the MacRecorder, provides movable markers and time bases to use with digitized frames.

The lead weights are grooved so that they can be pinched onto the string. If the weights are equally spaced, then the distance from the floor for each weight is *nd*, where *d* is the spacing and *n* is an integer. The free-fall equation with no air resistance and zero initial velocity is $nd = gt^2/2$, which can be expressed as

$$t = \sqrt{2nd/g} \tag{1}$$

where *d* is chosen to allow a reasonable time between collisions with the floor. Parameter *t* is the time taken for the weights to hit the floor, and *nd* is the total distance from the floor to each weight, with the spacing between weights equal to *d* and *n* = 1,2,3....

The difference in the time intervals between each weight collision de-

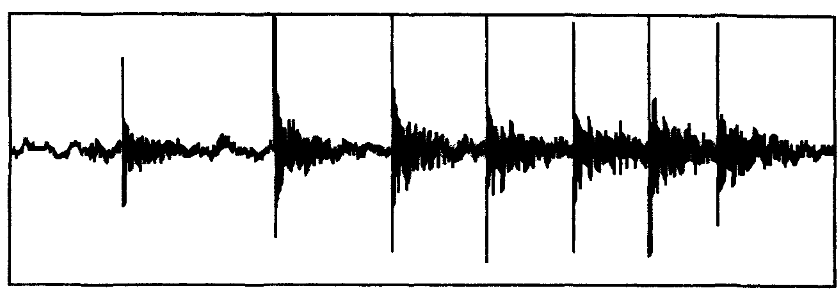

Fig. 1. MacRecording of a string of weights hitting the floor. The weights are spaced at 0.304-m (1-ft) intervals.

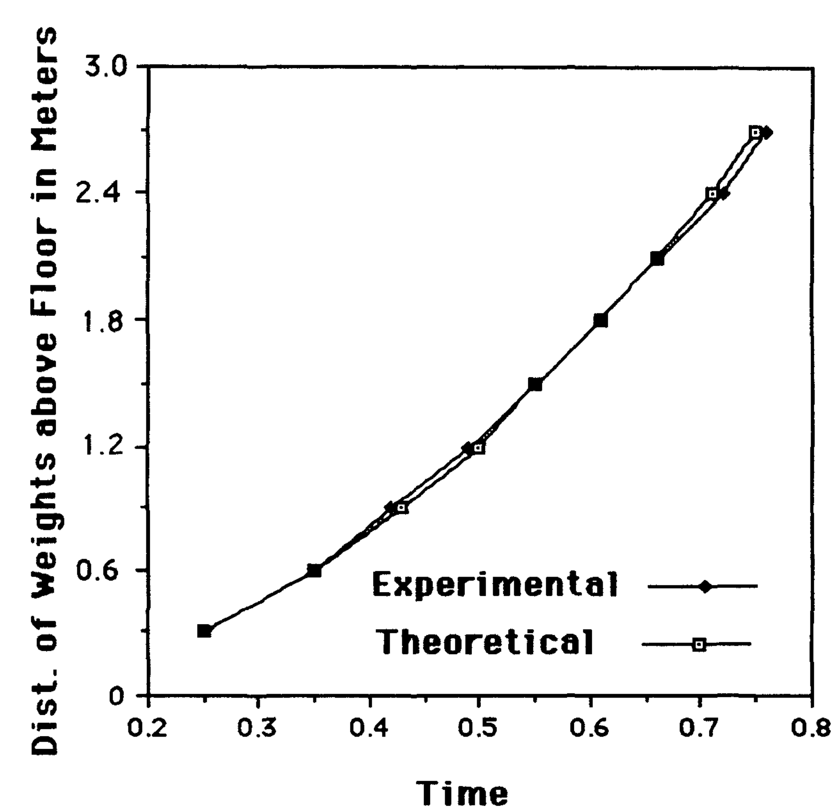

Fig. 2. Experimental vs predicted times of fall for equally spaced weights (from Fig. 1).

creases as the weight distance from the floor increases. This happens because each weight travels the final distance interval at a greater average speed. Thus the collisions with the floor increase in frequency as the string of lead weights falls.

In Fig. 1 we see that the time intervals between strikes on the floor decrease steadily when a string of equally spaced weights is dropped.

In Fig. 2 we see experimental data that is in very close agreement with theory. We can conclude that the weights fall essentially freely and encounter very little air resistance. The experimental value of g from Fig. 2 is 9.5 m^2, producing a discrepancy of about 3 percent.

What happens when the beads are spaced according to the free-fall equation? The free-fall equation can be written as

$$d_n = g\,(n\,t_0)^2/2 \qquad (2)$$

Parameter t_0 is the time interval chosen to be a constant, and n is an integer index for the interval. Figure 3 is a recording of five falling weights spaced to hit at ⅛-s time intervals. It is important that the first weight be spaced at the exact calculated distance above the floor before dropping the string (or the first weight can be placed barely touching the floor), so as a precaution we taped the bottom of the string to the floor.

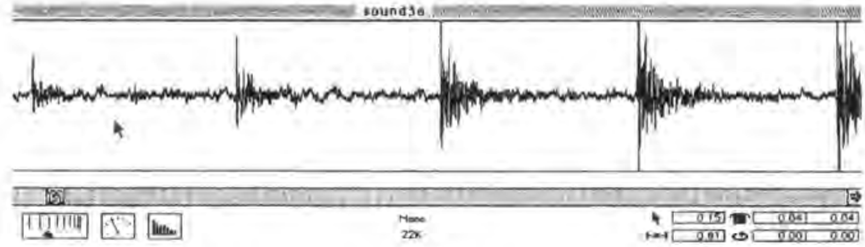

Fig. 3. MacRecording of a string of weights spaced to hit the floor at ⅛-s time intervals.

The time intervals in Fig. 3 are all very nearly equal, as expected. An analysis of these recordings gives times between collisions of ⅛ s ±2 percent. The error is probably due to air friction acting on the longer string needed for equally spaced collisions.

Conclusion

We find the MacRecorder to be an effective tool for recording and analyzing audible events. The MacRecorder (or any other sound digitizing device such as the Sound Impact Pro) and the built-in microphone that comes with the new Macintosh, along with the software available for analysis of sounds, increases our ability to perform a variety of novel physics experiments.

For example, as one variation in this free-fall experiment we substituted a much heavier weight for one of the equally spaced small weights. The heavy weight behaved as if it were a small weight, just as Galileo had predicted. This result generated some excitement among our students, since most of them had predicted that the heavier weight would pull down the lighter ones. Until they encountered this exercise, our students had given little thought to Galileo's fabled comparison of falling weights. This apparatus made it simple to bring history and science together.

References

1. R.D. Edge, "Dropping a string of marbles," *Phys. Teach.* **16**, 233 (1978).
2. R. Beichner, "Using Macintosh computers in physics labs," *Phys. Teach.* **27**, 348 (1989).

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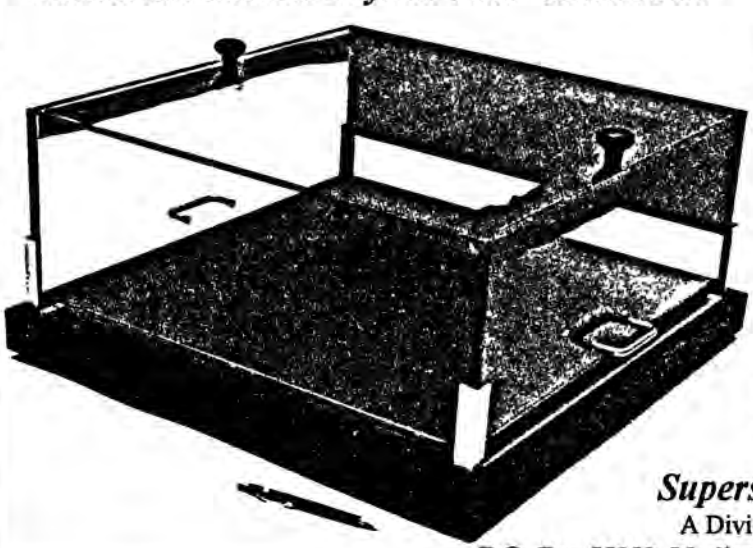

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