d, v, and a for Falling Putty Knife

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Making and analyzing graphs of
distance, velocity, and acceleration.

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1. With a cell phone video camera set to at least 240 frames per second (fps), record a putty knife falling in front of a measuring tape fastened to a wall. See the resulting attached video “Putty Knife Falling 240 fps Start at f6.mov”.
2. The putty knife is flat, so it has little parallax distortion of its distance measurements.
3. The measuring tape is the kind used for clothing measurements, so it has alternating light and dark sections for decimeters.
4. If the video resolution is the normal 30 fps, there is not enough time resolution, and the falling object looks like a blur.
5. Play the video with Apple’s QuickTime Player because you can easily change the lower left seconds to more precise frames.

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5. Students record into the attached spreadsheet “Falling Putty Knife, Fill in Distances, Copy Formulas.xlsx” the putty knife’s straight edge positions on the measuring tape for different times in frames. Now, view the spreadsheet and its graphs.
6. After entering the time and position data into the spreadsheet, students copy and paste into the different columns the formulas for time (in seconds), velocity, acceleration, etc.
7. Then, the time graphs of distance, velocity, and acceleration appear in the spreadsheet. Students compare their calculated measurements with the predicted values.

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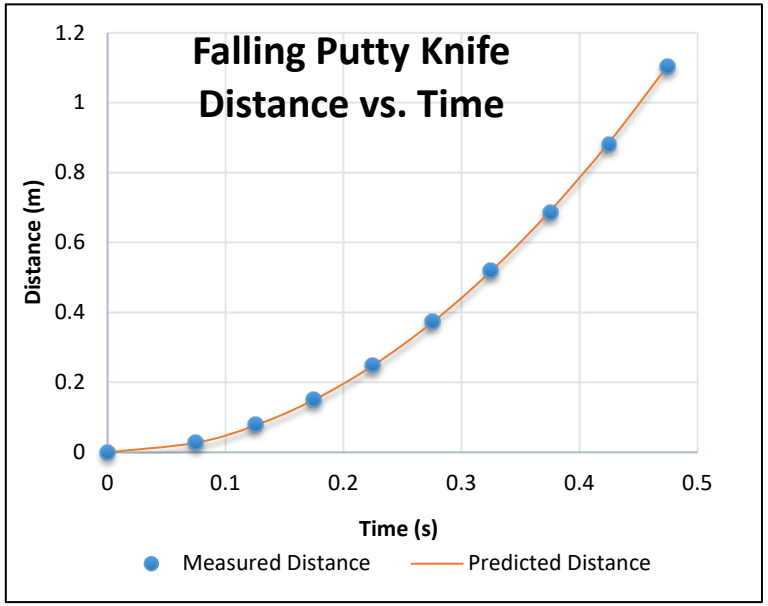
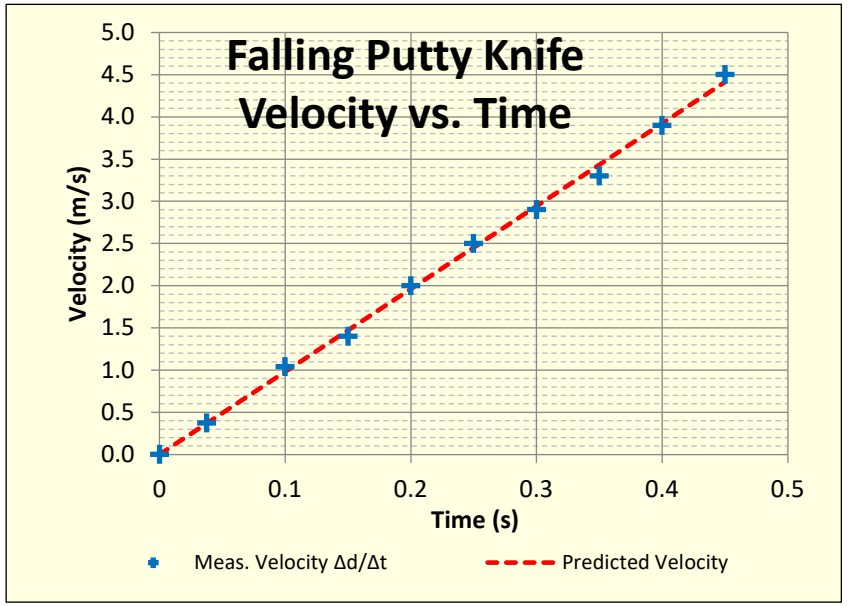
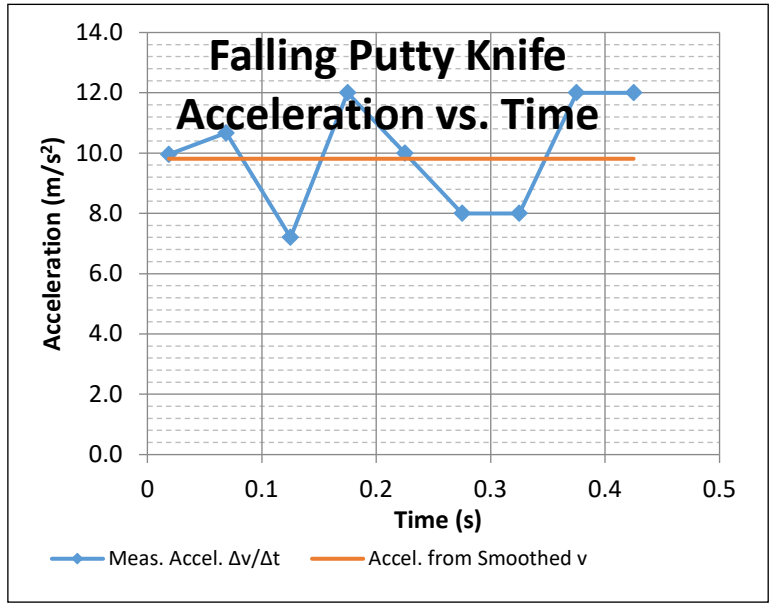
Spreadsheet graphs of distance, velocity, and acceleration for a falling putty knife.







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8. Newer cell phones have better resolution, but the lower resolution has these advantages:
    a. Students develop the skill of estimating the last decimal place. For example, instead of recording a distance of 0.5 meters, they record a distance of 0.52 meters.
    b. With less resolution and precision, students see the effects of data errors. For example, instead of determining the velocity at 0.3 seconds by calculating the slope on the distance graph between 0.275 and 0.325 seconds, they use the best fit line through the calculated velocity data points.
    c. Then students calculate the acceleration as the slope of the best fit velocity line. Otherwise, their acceleration calculations have serious errors.

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9. Students learn that the slope of position is velocity and the slope of velocity is acceleration on time graphs.
10. Students check that the area between two times under the acceleration curve (or line) is the velocity change between those times.
11. Students also check that the area between two times under the velocity curve is the position change (displacement) between those two times.
12. Students complete the attached “Worksheet, Falling Putty Knife d, v, and a.docx”.