Paratroop Drop Activity

Materials:
Shaving cream, plastic container, small objects (the paratroopers), string, wooden skewer.

Part I: Vertical Drop, Qualitative Investigation.

Fill the container with shaving cream. Smooth out the top as best you can, in order to make a flat surface.

(a) Drop a single object (e.g. a marble) into the container, noting the initial height and final depth. (How are you going to determine the final depth?)

(b) As the marble falls, its potential energy is converted to kinetic energy, but eventually the marble loses all of its kinetic energy as it plows through the foam. Create a sketch that could be called an "Energy Flow Diagram" for this situation that you think would be understood by your students.

(c) Repeat part (a) for a series of different initial heights. (It's not necessary to remove the marbles or otherwise "fill in" their tunnels created by a marble.)

(d) What can you say about the relationship between the intial height H and final depth D?

(e) Suppose you were to repeat part (c) using a different kind of object (e.g., larger marbles). Do you think these marbles will sink more, the same, or not as far as the original objects? Try to justify your inuition.

(f) Now try out the "hypothetical" you considered in part (e). Was your intuition right? If not, how can you understand what actually happened?

(g) (optional) Make a qualitative graph of "energy versus time". First, sketch the marble's potential energy (vertical axis) versus time (horizontal axis). Indicate on your graph the instant when the marble first contacts the foam, and the instant the marble first comes to rest. Second, on this same plot, draw the marble's kinetic energy (vertical axis) versus time (horizontal axis).

Part II: Vertical Drop, Quantitative Investigation.

Remove the marbles (and other objects) from the foam, smooth out the top, adding more shaving cream as needed. Clean off and dry the recovered objects.

(a) Using the smaller marbles, make measurements of the initial drop height H and the corresponding tunnel depth D.

(b) Use your measurements to make a graph of H (vertical axis) versus D (horizontal axis).

(c) Draw the "best" straight line through the points on your graph, and determine the slope of the line (slope = rise over run). If you knew the weight *W* of the dropped object, your experimental estimate of the force exerted by the foam on the marble would be

$$F = s \times W$$

where *s* is the slope of your graph.

(d) Even if you don't know (and can't otherwise determine) the weight of the marble, you can easily find the so-called "g-force" exerted by the snow on the marble:

$$\text{g-force} = s \times g$$

where *g* is the acceleration of gravity due to the Earth. In fact, the g-force is the more relevant quantity when it comes to the Soviet paratrooper story. Read on.

(e) Could the story of the WWII Soviet parachute-less paratroopers be true? The key point is that a person will not survive an impact having too large a g-force. Estimates of the "maximum survivable" value vary, but U.S. National Highway Traffic Safety Administration standard is that a g-force larger than 50 *g* is likely to cause serious injury.

So, let's try to make a reasonable estimate. Suppose our hapless Russian drops

$$\text{g-force} = \left(\frac{150\ \text{ft}}{2\ \text{ft}}\right)\ g$$

from a low-flying plane 150 feet above the ground, and sinks 2 feet into the snow. Then:

which is 75 *g* -- too much, according to the USNHTSA! On the other hand, this is only an estimate: if the drop altitude is decreased and/or the snow is "fluffier" (so that the paratrooper sinks farther into the snow), it might be possible to beat the 50 *g* limit.

Part III: Follow-up.

If energy can only be transformed from one type to another -- but never created or destroyed -- where did the energy go? That is, initially the marble has potential energy, but finally it has neither potential nor kinetic energy. Does the "energy flow diagram" you created earlier account for this "lost" energy? If not, see if you can modify your diagram so that it does.