Teaching module – crater formation

An investigation into the factors which affect the size of craters formed in sand by falling objects

Choice of variables

Students are invited to consider the factors which may affect crater size. E.g. height of drop, mass of dropped object, size (diameter) of dropped object, dampness of sand, type of sand. Experience has shown that the first two of these provide results which are possible to interpret.

Hypothesis

Depending on the age of the students, ask for a specific hypothesis about how the size of the crater will change as the chosen variable will change – eg if height of drop doubles, crater size will double, etc.

Older students can be encouraged to think about specifics. E.g. kinetic and potential energy, work done in creating crater, etc.

Control of other variables

Ask pupils to choose the variable they want to vary (mass or height) and then to make a list of the other possible variables that they will keep constant.

Discuss why this is so important. (eg if you change two things simultaneously, you can't decide which is responsible for changes.)

Preliminary trials

Ask students to suggest a sensible range over which measurements might be made. Eg heights from 1cm to 3m might be considered.

A few tests should be attempted, to see if the results are reasonable, before measurements start.

Collection of data

In order to get a good range of values, drop-height might range from 10cm to 1m in steps of 5cm.

Varying the mass is easily done by using a table-tennis ball, carefully punctured (a hot soldering-iron is good) and loaded with sand. The entry hole can be taped over during the experiments.

The size of the crater can most easily be estimated by measuring its diameter. Another, more difficult, method is to measure the volume of sand needed to refill the crater. This is also more complicated to give a theoretical treatment of the results, but the best students will find it possible.

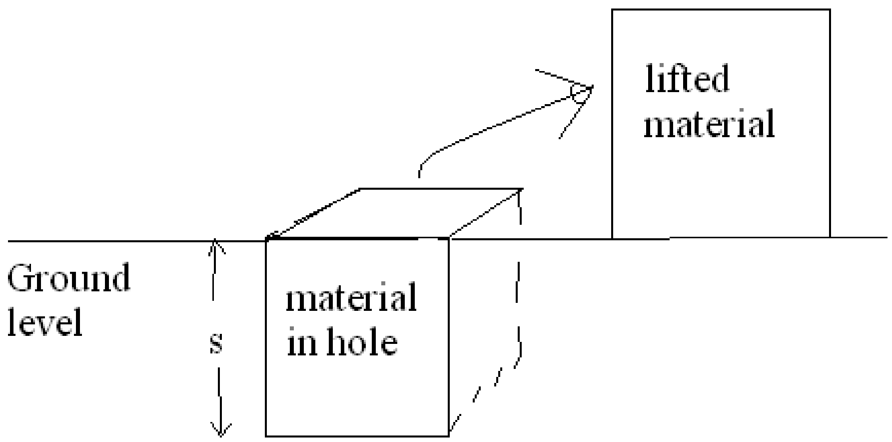
Whichever is chosen, get students to suggest why it is a good idea to repeat measurements and to average results in order to get reliable readings.

Theory

Here is an approach you may find helpful:- the formation of a crater is akin to digging a hole.

To start with let us consider the minimum potential energy change that occurs when a cubic hole, side-length s, is created in sand.

This will be the same as lifting a similar-sized amount of material onto nearby ground.



Volume of hole = s^3 m^3

Mass of material moved from hole
= volume x density = s^3 m^3 x d kg/ m^3
= s^3.d kg

Weight of this material = m x g = s^3.d.g N

Potential energy gained = weight x height lifted =s x s^3.d.g = <u>s^4.d.g</u>

So PE gained by material from crater is proportional to (size of crater)^4.

This will be true as the scaling factor for *any* shape of crater. So for our purposes, we just need to check that the shape of the crater is about the same for each of our measurements.

Where did this energy come from? The Kinetic Energy of the falling ball just before impact.

This KE will be equal to the Potential energy lost by the ball during the fall.
PE lost = weight of ball x height fallen
= mass of ball x g x height fallen = m.g.h

ie m.g.h is proportional to s^4.d.g x (a factor due to the shape of the crater).

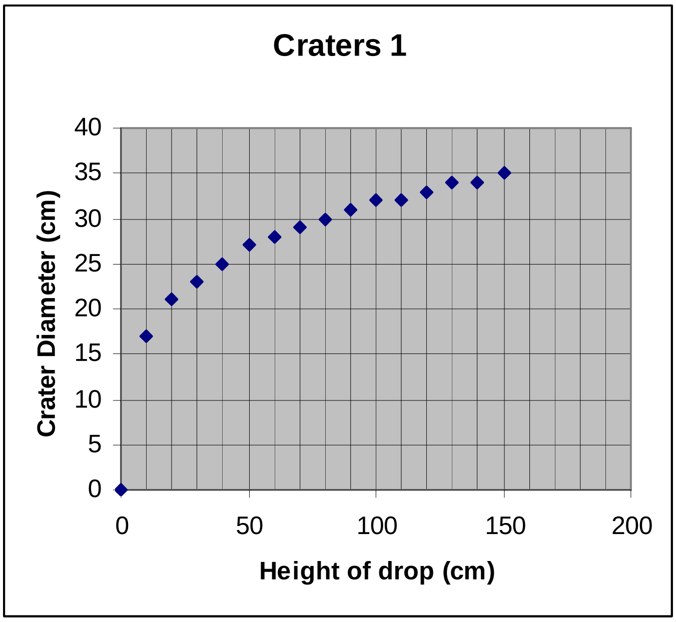
Thus a graph of mass of ball, or height of drop (whichever is used) vs (size of crater)^4 should yield a straight line since d, g and the craters' shape are all constant.

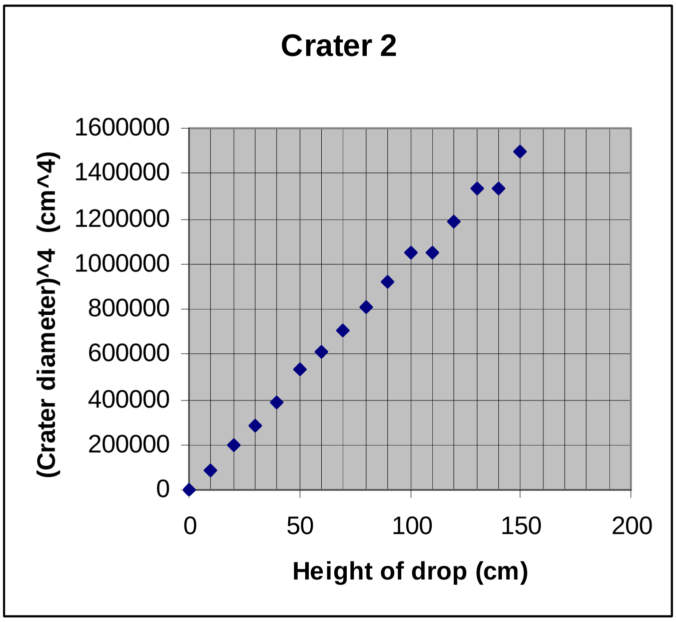
Possible extensions to this work

It might stimulate the students if they are asked 'is this relationship always true, or might it be different if the range of the experimental results were different?'.
For example, if the impact speed were very large, the crater may change shape to be more tunnel-like, as would be the case if the sand were hit by a rifle bullet.

Sample results

height(cm)	diameter(mm)	$diameter^4$ $(mm)^4$
0	0	0
10	17	83500
20	21	194000
30	23	280000
40	25	391000
50	27	531000
60	28	615000
70	29	707000
80	30	810000
90	31	924000
100	32	1050000
110	32	1050000
120	33	1190000
130	34	1340000
140	34	1340000
150	35	1500000





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