How does the drop height of the marble affect the size of the crater in sand? ess...

Impact craters are geologic structures formed when a large meteorite, asteroid or comet smashes in to a planet or a satellite. Meteorites are small rocks in space that hit the earth’s atmosphere at a high velocity. Throughout their history they have heavily bombarded all the inner bodies in our solar system. In this experiment we will use marbles as our meteorites, these will be free falling objects that will be used to copy an asteroid impact. The surfaces of the Moon, Mars and Mercury, where other geologic processes stopped millions of years ago, record this bombardment clearly. On the Earth, however, which has been even more heavily impacted than the Moon, craters are continually erased by erosion and redeposition as well as by volcanic resurfacing and tectonic activity. Thus only about 120 terrestrial impact craters have been recognized; the majority are in North America, Europe and Australia where most exploration has taken place. The force that makes meteorites fall is gravity. Gravity attracts anything with a mass. The bigger the mass the greater the gravitational pull. The earth’s gravitational field attracts meteorites and causes them to collide with the earth’s surface.

Here are two examples of craters: –

In this experiment it is more likely that the shape of the crater will resemble the top diagram as the shape of the marble is circle and so it will form a simple crater. Below is another diagram of a common crater in more detail: –

The floor is bowl shaped or flat normally below surrounding ground level unless filled in with lava. The ejecta is a blandet of material surrounding the crater that was dig up during the impact event. The raised rim is caused when the rock is thrown out of the crater and deposited as a ring-

shaped pile of debris at the crater’s edge during the explosion. The walls of a crater are usually steep and may have giant stairs called terraces. The rays are bright streaks starting from a crater and extending away for great distances. Finally the central uplifts are mountains formed because of the huge increase and rapid decrease in pressure during the impact event. They occur only in the centre of craters that are larger than 40 km diameter.

The amount of gravitational potential energy an object has depends upon its height above a surface. To work out the potential energy you need to use this equation

Work done = force x distance

Potential energy = mass of object x height of mass x gravity

PE = mgh

So the higher the object is the more potential energy. Doubling the height would double this energy. As the object falls, this energy gets changed into Kinetic Energy (i. e. the object is moving faster when it hits the sand). When an object reaches the ground it is at maximum kinetic energy. This is the formula used to work out kinetic energy: –

Work done = force x distance

= mv/ t x h

= ½mv”

Kinetic energy = ½ x mass x velocity”

To use this formula we will need to work out velocity

V = u +at”

Velocity = initial velocity + acceleration x time

The initial velocity is zero, and all objects with mass have an acceleration of 9. 8 m/s” because of the earth’s gravitational field. We still need to work out time; we can do this by rearranging the formula.

s = ut + ½ at”

Distance = initial velocity x time + ½ acceleration x time”

The initial velocity is zero and the acceleration is 9. 8 m/s”. The Distance in the equation is s and so we can rearrange the formula to make Time t the subject.

t = Ös/0. 5 x acceleration

Once we have found out the velocity we can use this formula to find the kinetic energy.

KE = ½mv”

Kinetic energy = ½ x mass x velocity”

The impact energy should equal maximum kinetic energy, if law of conservation holds. The sand into which it falls has to get rid of this energy, and it does this by compressing the sand, and by throwing some of it up in the air, and also by producing heat, light and sound. Doubling the height of

the object will make a deeper crater because as you increase the height the potential energy gets greater.

Below is a diagram showing all the energy conversions involved: –

Some important factors that affect the size of the crater are, the weight of the marble, the size and shape of the marble, the depth and type of sand, the material of the marble and the speed at which the marble is thrown.

Prediction

I predict that as the height at which the marble is dropped increases, the size of the crater will also increase. This will be the same with both marbles. The reason for the increase is due to the increase in kinetic energy as indicated by PE = mgh. Also as the height increases so does the potential energy and consequently so does the kinetic and impact energy. The marble has gravitational potential energy and when it is higher it gains more energy and so this has a greater force on the sand making the crater bigger. Therefore I predict the graph to look like this: –

Apparatus

o Plastic tub

o Fine sand

o Large marble

o Small marble

o Clamp

o Ring stand

o Table

o Meter stick

o Notebook

o Pen

o Weighing scales

Diagram

Method

o Set up apparatus as shown, making sure that the meter stick is placed vertical near the edge of the sand tub and. It should also be level with the sand.

o Start with the small marble and drop it from 10cm, do not apply any force to the marble and make sure it lands somewhere in the middle of the tub.

o Once it has landed in the sand, carefully remove the marble and measure the diameter of the hole (crater) it has created, using a compass.

o Repeat test with higher measurements increasing the height by 10cm each time.

o Repeat the test 3 times

o Repeat the whole experiment again using a larger marble.

o Record all results

Fair test

o Set up apparatus accurately and make sure everything is level.

o Change the height at which the marble is dropped. Take eye-level results.

o Keep the size of the marble constant.

o You are measuring the size of the crater in millimetres.

o Make sure the sand is sieved and doesn’t have any lumps.

o Use the same type of sand for both experiments.

o Repeat test at least 3 times.

o No force should be applied on the marble.

o Make sure the sand is levelled.

o Keep the ruler vertical and just above the sand.

Variables

Independent variables

o Drop height of marble

o Size of marble

Dependant variable

o Size of crater

Constant variables

o Use the same type of sand

o Keep level of sand the same

o Same angle of drop

Safety

o Tie back lose clothing and hair.

o Clear work surface

o Concentration on experiment

o Move all bags, books, etc out of the way

Results

A table showing crater diameters made by a falling small marble. The mass of the marble was 0. 006kg.

Crater size (m)

Height (cm) Trial 1 Trial 2 Trial 3 Average

0. 000 0. 000 0. 000 0. 000 0. 000

0. 100 0. 026 0. 024 0. 027 0. 026

0. 200 0. 029 0. 030 0. 030 0. 030

0. 300 0. 032 0. 032 0. 033 0. 032

0. 400 0. 033 0. 034 0. 034 0. 034

0. 500 0. 039 0. 037 0. 037 0. 038

0. 600 0. 040 0. 038 0. 038 0. 039

0. 700 0. 043 0. 040 0. 039 0. 041

0. 800 0. 045 0. 040 0. 043 0. 043

0. 900 0. 045 0. 034 0. 045 0. 041

1. 000 0. 041 0. 042 0. 040 0. 041

A table showing crater diameters made by a falling large marble. The marble had a mass of 0. 006kg.

Crater diameter (m)

Height (m) Trial 1 Trial 2 Trial 3 Average

0. 000 0. 000 0. 000 0. 000 0. 000

0. 010 0. 029 0. 028 0. 029 0. 029

0. 020 0. 034 0. 033 0. 032 0. 033

0. 030 0. 038 0. 037 0. 035 0. 037

0. 040 0. 042 0. 038 0. 038 0. 039

0. 050 0. 041 0. 036 0. 042 0. 041

0. 060 0. 040 0. 038 0. 045 0. 042

0. 070 0. 041 0. 040 0. 046 0. 042

0. 080 0. 043 0. 045 0. 047 0. 045

0. 090 0. 041 0. 043 0. 045 0. 043

1. 000 0. 047 0. 046 0. 046 0. 046

Calculations

A table for the small marble

Mass (kg) Drop height (m) Time (s) Velocity (m/s) Potential energy (j) Kinetic energy (j) Impact energy (j) Average crater size (m)

0. 000 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000

0. 006 0. 100 0. 143 1. 402 0. 006 0. 006 0. 006 0. 029

0. 006 0. 200 0. 209 2. 048 0. 012 0. 012 0. 012 0. 033

0. 006 0. 300 0. 247 2. 421 0. 018 0. 018 0. 018 0. 037

0. 006 0. 400 0. 286 2. 803 0. 024 0. 024 0. 024 0. 039

0. 006 0. 500 0. 319 3. 126 0. 030 0. 030 0. 030 0. 041

0. 006 0. 600 0. 349 3. 420 0. 036 0. 036 0. 036 0. 042

0. 006 0. 700 0. 378 3. 704 0. 042 0. 042 0. 042 0. 042

0. 006 0. 800 0. 404 3. 959 0. 048 0. 048 0. 048 0. 045

0. 006 0. 900 0. 429 4. 204 0. 054 0. 054 0. 054 0. 043

0. 006 1. 000 0. 452 4. 429 0. 060 0. 060 0. 060 0. 046

A table for the large marble

Mass (kg) Drop height (m) Time (s) Velocity (m/s) Potential energy (j) Kinetic energy (j) Impact energy (j) Average crater size (m)

0. 000 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000 0. 000

0. 021 0. 100 0. 143 1. 402 0. 021 0. 021 0. 021 0. 029

0. 021 0. 200 0. 209 2. 048 0. 041 0. 041 0. 041 0. 033

0. 021 0. 300 0. 247 2. 421 0. 062 0. 062 0. 062 0. 037

0. 021 0. 400 0. 286 2. 803 0. 082 0. 082 0. 082 0. 039

0. 021 0. 500 0. 319 3. 126 0. 103 0. 103 0. 103 0. 041

0. 021 0. 600 0. 349 3. 420 0. 123 0. 123 0. 123 0. 042

0. 021 0. 700 0. 378 3. 704 0. 144 0. 144 0. 144 0. 042

0. 021 0. 800 0. 404 3. 959 0. 165 0. 165 0. 165 0. 045

0. 021 0. 900 0. 429 4. 204 0. 185 0. 185 0. 185 0. 043

0. 021 1. 000 0. 452 4. 429 0. 206 0. 206 0. 206 0. 046

The equations I used to complete the table are the following: –

o Time = Ös/0. 5 x a

o Velocity = a x t

o Potential energy = mgh

o Kinetic energy = ½ mv”

Conclusion

In my prediction I stated that as the marble gets higher the crater would increase in size. By doing this experiment I have proved my prediction to be correct. My prediction was based on the scientific knowledge that as the marble gets higher it gains more energy; therefore there is a bigger force, which in turn will make the size of the crater bigger.

My results showed that the larger marble made a bigger crater than the smaller marble. This is simply because the larger marble had a bigger diameter and a greater mass, but both marbles still acted in similar ways

Although my results showed that the higher the marble, the larger the crater diameter they were still unusual. My predicted graph showed clearly this progression with a straight line, but after doing the experiment the graph

turned out to be a bit different. As you can see the diameter starts off increasing steadily but then the increase slows down and eventually the line decreases. After doing some research I have found out that the marble was gradually reaching its terminal velocity. This is when a falling object has reached its maximum velocity. This occurs when air resistance and gravity are both equal. I have learnt that when the marble reached its terminal velocity instead of penetrating outwards it penetrated within the sand and increased the depth. The marble compressed the particles underneath the sand instead of going outwards, which caused the crater size to become smaller.

This experiment related a lot with energy and how it is converted throughout the process. This experiment proves that no energy was destroyed. By looking at the table you can see that the potential energy is equal to the kinetic energy, which is equal to the impact energy. My results table shows the energy steadily increasing as the height increases. Potential energy is energy that is stored. The marble had potential energy when it was held in my hand as I let it go the potential energy was converted into kinetic energy as it hit the ground the energy was converted into impact energy, which was converted in to light sound and heat energy.

The calculation table proves that as the height increases so did the velocity as the marble had more time to reach its maximum velocity. This created a greater impact when the marble hit the surface, which affected the size of the crater. The table also shows that as the height increases the marble takes longer to reach the sand, this is because the marble had a greater distance to travel.

Evaluation

Overall I am quite pleased with how the experiment went. I think the procedure was fairly good, however there are certain things that could be done to make this experiment more realistic. For example you could have the force coming down in different directions, as this what it would really be like. Because meteors do not always hit the surface with a perpendicular angle the crater shape is elongated. In our experiment we dropped the crater at a 90° angle and the crater shape was more rounded.

There are also some factors that have to be considered. For example the surface of a planet may not be made of sand, however we used sand in our experiment. The surface is not flat either, but the tub of sand we used was actually flat. The meteors were also even and round in the experiment, but normal meteors would not be uneven and would be randomly shaped.

There were a few anomalous results in my graph. This could be due to the fact that I did not measure the size of the crater carefully and accurately enough, or I did not pay enough attention when dropping the marble from different heights. Also our equipment and way of measuring wasn’t as accurate because we couldn’t clearly see the rim of the crater and we were unable to know if the ruler was completely straight even with the clamp stand.

In order to resolve this I would need to repeat the experiment to obtain a wider range of results. If I had 5 sets of result I would be able to draw a better conclusion.

If I were to repeat this experiment I would repeat it 5 times and make sure that the ruler is completely vertical by lining it up with a vertical object e. g. a wall. Also the sand we used wasn’t fine grained and so we had to sieve it but it still wasn’t smooth enough. Next time I will make sure that I use very fine-grained sand. This will make the crater more visible and the whole experiment more reliable as the marble will have a better surface to land on.

To follow on from this experiment we could investigate how the depth increases and try releasing the marble from different angles. Also in our experiment we only measured the diameter from one particular part. As the crater is not always perfectly round we could have taken several readings for the diameter and then found the average.