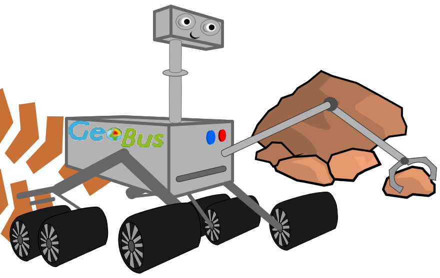
The Martian

Science Fact or Science Fiction?



Materials: Copy of *The Martian* on DVD, materials for supporting experiments/activities if using

Background: Perhaps surprisingly, compared to many other space themed movies, *The Martian* is actually quite accurate with only a few points which are completely untrue. In this activity, selected clips of scientific importance/key situations are used as the base for a discussion on the accuracy of science in popular films.

This can either be carried out as a simple class discussion around the selected scientific elements of the film, or can be combined with the more in-depth activities/experiments in the 'Science Fact or Science Fiction' pack. The clips have been chosen to make sense even when viewed individually, but it may help to read out a short description of the film plot for anyone who hasn't seen it (or ask a pupil who has to give an overall description).

When a group of astronauts blast off from Mars, they leave behind Mark Watney, presumed dead after a fierce storm. With only a small amount of supplies, he must use his wits, knowledge and spirit to find a way to survive – hoping someone will realise he is still alive and come back for him!

Time: Dependant on activities incorporated – to show all movie clips and work through explanations given takes **approx. 35-40mins**

Instructions: Clips from the film are given as times (hh:mm:ss), the corresponding 'chapter' (some as log entries) in the book is also given – please note that it contains some bad language.

After watching each clip, get the pupils to discuss and vote whether the depiction is realistic or not (either as a class, or encourage pupils to discuss in small groups and decide how the 'team' will vote)

The downloadable powerpoint 'The Martian: Science Fact or Science' gives the answer and explanation for each clip

The Storm 00:03:53 – 00:04:54 LOG ENTRY: SOL 6

Science FICTION: the strength of the storm is not realistic - you do get dust storms on Mars but they are not this strong. The Martian atmosphere is only 1% as thick as Earth's, so a Mars wind of 100mph - possible although quite rare on the surface - would only have the same force as a 10mph wind on Earth.

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The Martian

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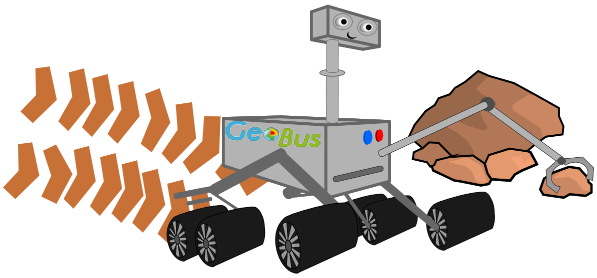

Surviving on Potatoes 00:20:38 – 00:21:34 LOG ENTRY: SOL 26

Science FACT: potatoes are pretty high in almost all minerals, vitamins, and macronutrients the human body needs to survive. As part of an experiment, one man survived on nothing but potatoes for 60days. He was eating 15-20 potatoes (2000cals) a day compared to the 1 (162cals) Mark eats in the film – but gravity is less strong on Mars so Mark would be using less energy AND he was supplementing his potatoes with rationed freeze dried food … so he might have been able to survive.

Fertiliser 00:23:24 – 00:24:17 LOG ENTRY: SOL 14

Science FACT: Human and animal waste has been used as a fertiliser on Earth throughout history, although bio soils today are heavily treated. This is because every human carries pathogens that can cause illness (viruses, bacteria, parasites) which could be transferred into the plants.

Making water 00:24:37 – 00:28:00 LOG ENTRY: SOL 30

Science FACT: Mark Watney took hydrazine from the rocket fuel and split it into nitrogen and hydrogen, which is possible, then burned the hydrogen with oxygen to make water. However, scientists have said that if they were stranded on Mars they would simply extract water from the ground: on Mars water can be found as ice, permafrost or contained within the soil.

Growing plants 00:28:34 – 00:28:56 LOG ENTRY: SOL 26

With the addition of fertiliser it really would be possible to grow potatoes in Martian soil. However, wet chemical analysis of the soil on the surface of Mars has shown it to be 0.6% perchlorates (salts capable of disrupting the body's metabolic system) so you'd have to take care.

Gravity Assist 01:23:33 – 01:25:05 (Chapter 16)

Michael Minovitch - a trajectory analyst at NASA's Jet Propulsion Laboratory in 1960s - came up with the idea of the gravity assist that became the basis of the Voyager programme to Jupiter, Saturn, Uranus and Neptune. Minovitch literally had to get out the chalk and walk them through the theory to convince them that it would work – just like the character in the movie.

Window-less launch 01:45:08 – 01:45:50 LOG ENTRY: SOL 549

The atmosphere is very thin, so can you get high enough that the atmosphere becomes irrelevant, before you're going fast enough that it would matter. It depends on the thrust profile (acceleration and speed), but lots of mathematics proves it is possible … if scary!

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Activity List

Potato Power: *using the energy of a potato to power a light bulb/clock*

Information: This activity follows on from the 'Surviving on Potatoes' film clip [00:20:38 – 00:21:34] and demonstrates the energy contained within a potato by hooking it up to a light bulb (or clock) as the 'battery'.

See also: https://goo.gl/knEgxy

Time required: 15-20 minutes

Potato Calories: *calculating the calorific content of an average potato*

Information: This activity also follows on from the 'Surviving on Potatoes' film clip [00:20:38 – 00:21:34] and involves estimating the equivalent calorific content in different foods [1], measuring the calorific content of a potato [2] and calculating how many potatoes an average person would need to eat to survive for the same length of time Mark Watney managed to on Mars [3].

See also: *http://www.calorificapp.com/* (examples of 200 calories)

Time required: [1] 10 mins

[2] 20-30 mins

[3] 5-10 mins

Salty Soil: *demonstrating the influence of salt on the freezing point of water*

Information: This activity follows on from the 'Making Water' film clip [00:24:37 – 00:28:00] and involves using food colouring to identify the different melting patterns in fresh water ice vs. salt water ice – highlighting that salt can lower the freezing point and hence salts in the martian soil may mean conditions allow for liquid water at the surface.

Time required: [NEED TIME FOR ICE TO FREEZE – ideally overnight]

10-15 minutes

Extracting water: *demonstrating the removal of moisture from soil using energy*

Information: This activity also follows on from the 'Making Water' film clip [00:24:37 – 00:28:00]. It uses a microwave to demonstrate that heating soil (particularly during the efficient addition of energy in the form of microwaves) can release moisture.

Note: This activity requires a microwave so it may be better carried out in small groups, or given as a homework/extra credit exercise?

Time required: 5-10 minutes (longer if repeating with multiple soils)

Other suggested activities

Rocket Launch: *how aerodynamics/launch angle control speed/distance travelled*

Information: This activity follows on from the 'Windowless launch' film clip [01:45:08 – 01:45:50]. Effective matchbox rockets can be easily built following the steps in the video below – modify the design using small amounts of cardboard and tape to create rockets with different 'bodies' [**note that a clear 3-4cm at the top of the rocket is required to ensure it doesn't catch fire rather than launching!**].

Safety note: Rockets should be launched outside and care should be taken that they are not aimed at people or animals. Once launched the rockets will be hot, so care should also be taken retrieving them.

Instruction link: *https://www.youtube.com/watch?v=WFyKgmnCF-8*

Instruction steps:

1. Trim the point of a wooden skewer so there is still a narrowing, but it is no longer sharp, and cut to approx. 15cm long
2. Cut a rectangle, about 5cm by 15cm, of aluminium foil
3. Lay the skewer across the foil, so that the point is 2/3rd across
4. Cut the head off a matchstick and place at the end of the skewer
5. Roll the foil tightly around the skewer + matchstick head
6. At the end with the matchstick head, tightly squeeze flat and fold down the excess foil, then crimp (with pliers) to ensure a seal
7. Design rocket how you'd like (make fins, wings, windows etc.) but take care not to make any holes in the foil
8. Make a stable stand with a hole to place the free end of the skewer in
9. [OUTDOORS] Place the rocket on its skewer in the stand
10. Light a tea light underneath the rocket head & step back … wait for the launch!

Moving to Mars: *estate agency challenge*

Consider the challenges that would need to be overcome for humans to settle on Mars – who would be up for being the first to go? What are the pros and cons, and what home comforts would make the difference? Challenge pupils to work in groups to think about these factors and try to create an estate agency advert (or video) selling a place on Mars.

Don't forget you might need to bring;

- a high tolerance for cold, loneliness and radiation
- lifetime supply of breathable air and food
- multibillion pound spaceship
- a desire to just get away from it all
- water
- tolerance to dust

Science Fact or Fiction?

Potato Power

Instructions

Materials Needed:

Two Potatoes
Two short pieces of heavy copper wire
Two common galvanized nails
Three alligator clip/wire units

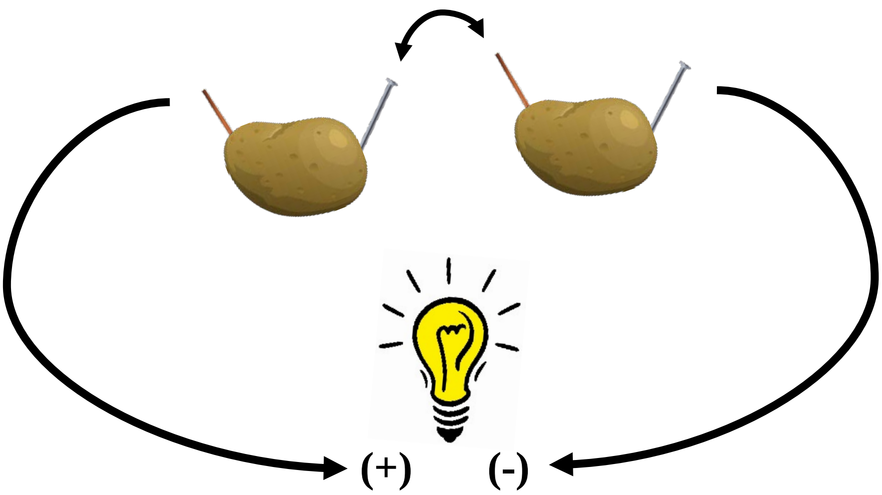
One light bulb unit
OR
One low-voltage LED clock (uses a 1-/2-volt button battery)

Instructions:

[If using a clock, first remove the battery from the clock, noting which is the positive (+) and negative (-) connection]

1. Take one of the potatoes and insert a nail in the end
2. Insert a piece of copper wire in to the other end (as far from the nail as possible)
3. Repeat steps 2 & 3 for the other potato
4. Use one alligator clip to connect the copper wire in the first potato to one terminal on the bulb unit / (+) terminal in the clock's battery compartment
5. Use another alligator clip to connect the nail in the <u>other</u> potato to the other bulb connection / (-) terminal in the clock's battery compartment
6. Use the third alligator clip to connect the nail in the first potato to the copper wire in the second potato
7. You should now see the bulb light up (or be able to set the clock and watch as it is powered by the potato batteries)

Tip: Make sure the wires are connected in the correct order or the circuit won't be complete and nothing will happen!



Science Fact or Fiction?

Potato Power

Potatoes hold a lot of energy – not only in the form of calories we can get by eating them but also as a battery to power more than just our bodies …

Draw and label your experiment

Describe your observations - was it expected or not?

Describe how the potato works as a battery?

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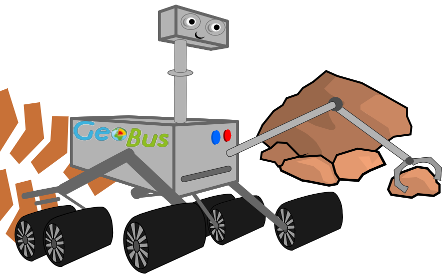
Science Fact or Fiction?

Potato Calories

Instructions



Materials:

[1] What does 200 calories look like?

Food labels showing calorie content
Scales
Plates
Examples of different foods
Data sheet showing weight of 200 calories per food (attached)

[2] How much energy does a potato contain?

20ml water *(*if using a different volume see note below)*
Boiling tubes + stands/tongs to hold
Thermometer
Potatoes
Knife (to cut potato)
Chopping board/plate
Safety equipment (i.e. goggles)
Long skewer/burning dish for Bunsen (to contain burning potato)
Bunsen burners
Scales

[3] How many potatoes to survive?

Value for calories contained per unit weight in a typical potato *(calculated from [2] or taken from data sheet)*

Calculators

Activity [1]: What does 200 calories of different foods look like?

1. For each food, try to estimate what size of portion would be equivalent to 200 calories and put this on one plate.
2. Use the scales to weigh out the right amount on another plate and compare this with your estimate. Which foods are surprisingly high or low in calories?
3. Use the food labels to consider the calorie content of other items. You can also calculate the rough calorie content by knowing how many grams of carbohydrate, protein, and fat a food contains:

   1 g carbohydrate = 4 calories
   1 g protein = 4 calorie
   1g fat = 9 calories

   Multiply the number of grams by the number of calories in a gram of that food component. If a serving of potatoes has 10 grams of fat, 90 calories are from fat - 10 grams x 9 calories per gram.

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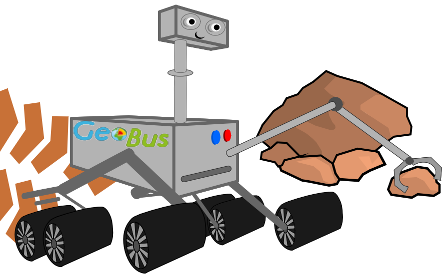
Science Fact or Fiction?

Potato Calories

Instructions



Activity [2]: How much energy is contained in a typical potato?

1. *(class)* Weigh the whole potato and make a note of the total mass
2. *(class)* Cut the potato into roughly $1cm^3$ cubes (one per group)

   [each group now has a set of equipment, and a piece of potato]
3. Pour 20ml cold water in to the boiling tube & record the temperature
4. Weigh the potato cube
5. Put the potato on the burning dish/skewer & heat until it catches fire
6. Heat the water using *only* the flame from the burning food until the food is completely burned
7. Record the final temperature of the water
8. Calculate the temperature increase
9. Calculate the energy released using the equation:

ENERGY = MASS x SPECIFIC HEAT CAPACITY x TEMPERATURE INCREASE

Specific heat capacity of water = 1 (cal/g.^{o}C)
Mass of water = 20g *(*20ml water weighs 20g, adjust if you use a different volume of water)*

Therefore:

ENERGY (cal) = 20 (g) x TEMPERATURE INCREASE (^{o}C)

10. Scale up the value to represent the whole potato - if the cube ($1cm^3$) weighs 2g and the whole potato weighs 100g, the conversion is 100/2 = 50, so multiply the energy value by 50. A typical nutritional Calorie = 1kcal (1,000 calories) so divide your answer by 1,000.

Activity [3]: How many potatoes a day would a person need to eat to survive?

1. Calculate the number of potatoes needed to survive 550 days by a person needing 1,500 calories a day (use the value from [2] or from the sheet

1,500 CALORIES PER DAY ÷ ENERGY PER 1 POTATO = NUMBER OF POTATOES PER DAY

NUMBER OF POTATOES PER DAY X 550 = TOTAL NUMBER OF POTATOES

Potatoes are pretty high in almost everything the human body needs to survive – they are more energy-packed than any other popular vegetable, and even have even more potassium than a banana. However, they don't contain much protein, which could lead to muscle wastage over time – so like Mark Watney in The Martian, anyone trying to survive on just potatoes would need to supplement them with vitamin and mineral supplements.

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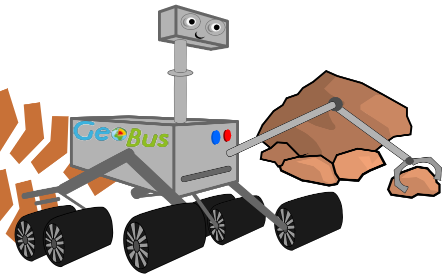
Science Fact or Fiction?

Potato Calories

Data Sheet (200cals)



Food	Weight of 200 calories
Apples	385g
Gummy bears	51g
Doritos	41g
Cheddar cheese	51g
Plain bagel	80g
Cooked pasta	145g
Eggs	150g
Ketchup	226g
Werther's Originals	50g
Mayonnaise	28g
Lettuce	1.43kg
Banana	224g
Peanut butter	31g
Cheerios	53g
Mini peppers	740g

100 g boiled potato = approx. 80 calories
A medium potato weights ~150g = 120 calories

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Science Fact or Fiction?

Potato Calories

How much energy is contained in a typical potato?

1. During the experiment, measure and record the values in the tables below:

Starting temperature	
Final temperature	
Temperature increase	

Mass of potato cube	
Mass of whole potato	

ENERGY = MASS x SPECIFIC HEAT CAPACITY x TEMPERATURE INCREASE

Specific heat capacity of water = 1 (cal/g.°C) so this value can be ignored
Mass of water = 20g *(*20ml water weighs 20g, adjust for different volumes of water)*

2. Calculate the energy in nutritional Calories released by burning the cube of potato:

$$\text{ENERGY (cal)} = \text{20g x TEMPERATURE INCREASE (°C)}$$

$$\text{ENERGY (Calories)} = \text{ENERGY (cal)} \div 1{,}000\ *$$

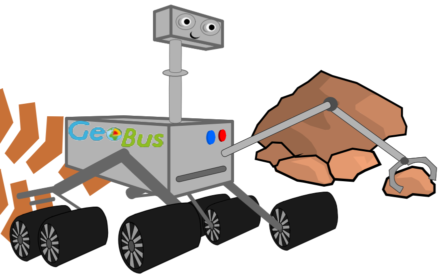
**divide by 1,000 because the typical nutritional Calorie is actually 1kcal (1,000 calories)*

3. Calculate the energy contained in a whole potato:

$$\text{ENERGY (whole potato)} = \text{ENERGY (cube) x } \frac{\text{MASS (whole potato)}}{\text{MASS (cube)}}$$

Science Fact or Fiction?

Potato Calories



How many potatoes a day would a person need to eat to survive?

In *The Martian*, Mark Watney needed to survive for the total of 550 sols (days).

An average person needs 1,500 Calories per day to survive.

Nutritional Calorie content of an average potato

1. How many potatoes would an average person need to survive 550 days:

1,500 CALORIES PER DAY ÷ ENERGY PER 1 POTATO = POTATOES PER DAY

POTATOES PER DAY X 550 = TOTAL POTATOES

2. During the film, Mark Watney only ate 1 potato a day – would this be enough to survive on? Why might ne need fewer calories a day than an average person?

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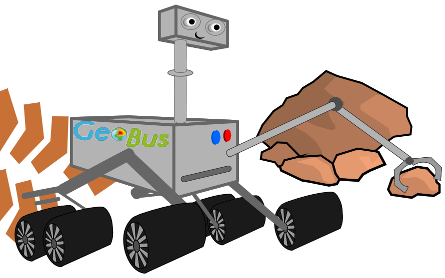
Science Fact or Fiction?

Salty Soil

Instructions



Materials:

Ice
Ice frozen with salt (sprinkle ~2tsp coarse salt per glass of water)
[large pieces of ice work best – try freezing in take-away dishes]

Large dishes/trays with sides
Liquid watercolours or food colouring
Dropper/spoon for colouring (plastic pipettes are great)
Coarse salt

Activity:

Place the pieces of ice in to the dishes/trays to contain the melting, and dot the surface of each piece with the colouring. The colouring won't colour the already frozen ice, but it should follow the melting pattern.

Keep an eye on what happens, and you should notice a difference between the salt water ice and the fresh water ice.

You can sprinkle more salt on top of the ice and/or add more food colouring to see what happens after some time has passed.

Discussion:

The salty water has a lower freezing point than the fresh water so it will start to melt sooner, forming channels in the ice. If you add more salt, it dissolves in the melted water, adding ions that decrease the temperature at which the water could re-freeze. As more ice melts, energy is drawn from the water, making it colder. Salt is used in ice cream makers for this reason - it makes the ice cream cold enough to freeze.

On Mars, temperatures are too low for liquid water to exist – is it possible that liquid salty water could exist?

There is evidence that Martian soils contain salts called perchlorates, which would lower the freezing point in the same way as in this experiment – based on estimated temperature and pressure conditions for the surface of Mars, it is possible that a perchlorate salt solution could be stable in liquid form for a few hours each day during the summer.

This could be good news for the possibility of life on Mars but is bad news for human exploration as perchlorates are toxic in high enough conditions.

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Science Fact or Fiction?

Salty Soil

This activity considers the different states of water and what influence salts present in the soil on Mars might have on the search for life.

What is the name of the salts found within soil on Mars?

Melting ice experiment:

You have several frozen dishes, some containing fresh frozen water and the others containing salty frozen water. Drop some food colouring on each bowl so that you can see the melting pattern, and describe what happens in each.

Can you tell contains salty water?

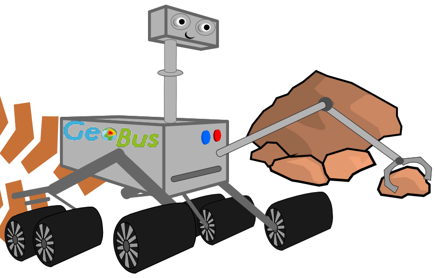
Liquid water is thought to be an essential ingredient for life as we know it, and there is life virtually wherever there is liquid water on Earth. As such, when researchers search for life elsewhere in the universe, they often look for places that could harbour liquid water.

Following the evidence from the experiment above, water could possibly have flowed on the surface of Mars with the help of salts in the soil that can melt ice, just as salts on Earth can be used to melt ice on slippery winter roads and pavements. Some researchers have suggested that this means *"the shallow subsurface of Mars could be habitable"*.

Science Fact or Fiction?

Extracting Water

Instructions



Materials Needed:
- Microwave
- Microwaveable tupperware/container
- Clingfilm
- Soil samples (collected from local area)
- Measuring jug (to measure water - optional)

Instructions:

1. Place some soil in a microwavable container
2. Cover the container tightly with cling film, so that no air can escape
3. Microwave on medium power in 20-30s bursts (for ~1 min)
4. Remove the container from the microwave and look closely at the cling film – is there any condensation?
5. If you wish, carefully remove the cling film and see how much water you can collect in a measuring jug
6. Repeat with different soil samples to see if there is any difference in the amount of water contained in the samples

How it works:

Microwaves are efficient at freeing bound water molecules from the soil, because they (the microwaves) are easily absorbed by the water molecules, heating them up and turning them to water vapour. The vaporised water then rises and condenses when it hits the colder cling film.

The microwaves essentially bake the water content out of the soil.

Other sources of water on Mars:

Atmospheric Water Vapour – 100% relative humidity has been observed on Mars but the atmosphere is very thin so the amount of available water is very small.

Ground Water – there is potentially liquid water in subsurface deposits (e.g. aquifers) on Mars (it's possibly these exist as salty solutions, see 'Salty Soil' activity).

Ice / Polar ice caps

Subsurface layers – "cryosphere" (e.g., permafrost)

Human missions to Mars will require a water source for consumption, as well as activities such as farming or manufacturing. Due to the absence of free water on the Martian surface, researchers are working to develop a unit capable of extracting water from the soil. The design has to be able to operate autonomously (with no on-site maintenance) and be able to withstand acceleration forces of up to 5G to survive the journey!

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