You are a scientist working as part of a team, investigating factors that affect life on Mars and Earth. The other scientists on your team have designed some simulations and videos and collected some data to help with your investigation.

Q1. a) Using Simulation 1, **identify one difference** between Earth and Mars and consider how it might impact life on Mars.

Simulation 1 - My observations and findings:

N.B. Simulation 1 only works on Chrome on Computers. It does not function correctly on Tablets/Phones or Safari.

Expected Responses:

- When the cursor is set to Earth the simulation shows what the Sun looks like from the Earth.
- When the cursor is moved to Mars the simulation shows what the Sun looks like from Mars. The Sun appears to be smaller and dimmer than when the cursor was at Earth.
- This could be because in our solar system the Earth is closer to the Sun, so it appears to be brighter and the light doesn't have as far to travel.
- On Mars the light has further to travel before it reaches Mars and the Sun appears smaller because it's further away.

Q1. b) Explain why some planets do not have water and why water might be found in different states on different planets, by **applying your observations from part a)** and examining the **first three columns** of **Table 1**. (Note: 0K = -273.15°C)

Expected Responses:

- In Table 1. the Daytime Mean Temperature values of different planets decrease as we look at the planets that are far from the Sun. This means that planets far from the Sun are colder, as expected. The simulation shows really clearly how small and far away the sun appears to be from the gas giant planets.
- I am surprised to see that there might be water on Mercury. All the other planets that are close to the Sun don't have water, which is what I expected because they are hotter planets.
- Earth seems to be in a "goldilocks" location, the perfect position from the Sun so it's not too hot or cold and we have water in all three states of matter.
- The Daytime Mean Temperature on Mars is very close to Earth's Daytime Mean Temperature however there is no water on Mars, so something else as

well as the distance from the Sun (and therefore temperature) must be a factor in why Mars has no water.

Q2. a) **Investigate another difference** between Earth and Mars, by examining the mass and core composition data of different planets, as outlined in **Table 1.**

Expected Responses:

- The mass of Mars is only a ninth of the mass of Earth.
- The planets Venus, Neptune and especially Jupiter have much more mass than Earth. This suggests that Mars is one of the planets with the smallest mass in our solar system.
- It is interesting that even though Mars has less mass than Earth they both have Iron and Nickel in their core.

Q2. b) The weight of an object is calculated by

$$W = mg$$

where W = weight in N, m = mass in kg and g = acceleration due to gravity in m/s^2
On Mars g = 3.7 m/s^2 but on Earth g = 9.81 m/s^2.
Calculate the weight of the objects on Mars by completing Table 2.

Table 2.

Object	Mass (kg)	Weight on Mars (N)	Weight on Earth (N)
Tennis Ball	0.06	W = (0.06)(3.7) = 0.2	0.5886
Football	0.43	W = (0.43)(3.7) = 1.6	4.2183
Car	1500	W = (1500)(3.7) = 5550	14715
The International Space Station	444,615	W = (444,615)(3.7) = 1,645,075.5	4,361,673.15

Q3. a) Working in groups to act it out, model the behaviour of water molecules when water is boiled in a kettle. Demonstrate your model for the other groups in your class and consider these questions:

1. **How would you describe** the movement of the water molecules?
2. Where are the molecules of water getting their energy?
3. **What happens** to the water molecules when the temperature reaches the boiling point of water?
4. **How could you apply** this model to molecules in a planet's atmosphere?

Expected Responses:

1. The water molecules start off perfectly still without movement. They begin moving as the kettle is switched on and the water starts to heat up and boil. They move more and more as the temperature of the water increases.
2. They are getting heat energy from the heating element of the kettle.
3. They have enough energy to move (kinetic energy) and collide with one another. Some of the molecules also begin to change state (to a gas) as they are continually heated. This is when they can escape the kettle as steam.
4. If the molecules of air in the atmosphere of a planet might be heated enough (maybe by the Sun) so that they can start moving around and colliding with one another. Some of the molecules might also escape from the atmosphere in the same way as steam from a kettle. These air molecules/particles might escape into space.

Q3. b) An atmosphere is made up of gases that orbit a planet. *Escape Velocity* is the velocity that a gas molecule in an atmosphere must have in order to overcome the pull towards the planet and leave the planet's orbit. The value of the *Escape Velocity* **depends on the mass of a planet**. Working in groups to act it out, **model the behaviour** of a molecule of Carbon Dioxide that reaches *Escape Velocity* and 1) leaves the atmosphere of Mars, and 2) leaves the atmosphere of Earth.

Q3. c) Using your model and video 1 and 2 , investigate how molecules in the atmosphere of a planet might get enough energy to reach *Escape Velocity*.

Expected Responses:

- In the model we used a ping pong ball (representing CO_2 in the atmosphere) taped to the end of a string (representing the pull towards Earth/Mars) and swung it around until the ball flew off from the string. The swinging motion represents the orbit that the atmosphere makes around the planet. The string pulls a molecule of CO_2 towards Earth/Mars and when the molecule escapes from that pull it is released from the atmosphere. The model doesn't show how the molecule gets the energy to reach that escape velocity. The molecule needs a source of energy to have enough energy to escape. *(the model works by using kinetic energy to swing the ping pong ball but it is not clear how this translates to a source of energy in reality when molecules reach escape velocity)*
- Video 1 shows the Sun and some plasma is emitted from the solar corona (atmosphere). Some of it is emitted in large clumps that look like lava erupting from a volcano. Other plasma appears to be streaming away from the Sun into space.
- Video 2 shows more clearly that smaller plasma particles appear to be streaming out of the solar corona (Sun's atmosphere). It looks similar to air movement in the wind on Earth. This is the solar wind.
- These videos show that the Sun is emitting plasma into space in the form of a solar wind, which keeps travelling through the solar system. This means that the solar wind passes Earth and Mars.
- The plasma that makes up solar wind is charged gas particles (mostly Hydrogen and Helium). These particles might collide with particles in the Earth or Martian atmospheres. The particles in the atmosphere then move and collide with more particles in the atmosphere, setting off a chain of movement like dominoes. If the particles gain enough energy through these collisions with the solar wind, they might have enough energy to reach escape velocity and escape the atmosphere of Earth or Mars.
- This could explain how particles of CO_2 in the Mars/Earth atmosphere get their energy to escape in reality (compared to our model).

Q3. d) Examine **Table 1** carefully. **Why do you think** molecules of Carbon Dioxide might be able to escape Mars' atmosphere more easily than other planets? You may wish to use diagrams in your answer.

Expected Responses:

- The first thing that I notice when I compare the escape velocities of the planets is that Mercury and Mars have the lowest values of escape velocity. They are both also much smaller than Earth (comparing mass values).
- I also notice that the atmospheric pressure of Mars is 0.006 but Earth's atmospheric pressure is 1. So Mars has an atmospheric pressure that's 0.6% of Earth's atmospheric pressure (i.e. much lower).
- Atmospheric pressure describes the pressure exerted by the atmosphere of a planet as it is pulled towards the planet's surface by the planet's gravity.
- This data in Table 1 tells me that it is much easier for a molecule of CO_2 to reach escape velocity on Mars compared to Earth.

Q3. e) The Carbon Dioxide in the Earth's atmosphere insulates the Earth and this is contributing to the climate crisis. Given that 95% of Mars' atmosphere consists of Carbon Dioxide, why do you think Mars is not also undergoing a climate crisis?

Expected Responses:

- Atmospheric gases such as Carbon Dioxide, Methane, Nitrous Oxide and Chlorofluorocarbons (CFCs) cause the greenhouse effect on Earth. This is where the gases act like a greenhouse, trapping heat in and warming the planet. Mars has only Carbon Dioxide (Table 1).
- Global warming contributes to the climate crisis on Earth. As well as this, since Mars has a very low atmospheric pressure this means it has a very thin atmosphere. This is why Mars has a low escape velocity.
- The escape velocity for Earth is 11,200 m/s which is more than double the escape velocity for Mars (Table 1).
- This means that CO_2 can easily escape from the thin atmosphere around Mars so it is not trapped and does not cause the planet to heat.

Q3. f) In 2021, scientists discovered that the clay and rocks on the surface of Mars contain water. They think that over half of the water that used to be on Mars, billions of years ago, was absorbed into its crust.

i) What way do you think Mars might have lost the rest of its water?

ii) What do you think would happen to **Earth's water cycle** if the Earth was the same **distance** from the Sun as Mars and had the same **atmospheric pressure** as Mars?

Expected Responses:

- i) Mars might have lost its water to space the same way that it loses its CO_2, because of its low atmospheric pressure (resulting in a thin atmosphere) and its small escape velocity value.
- ii) If Earth was the same distance from the Sun as Mars then water would probably take longer to evaporate from the surface and condense as water vapour in the atmosphere than it normally does, because Mars is located further from the Sun than Earth (see Q1)
- ii) contd. If Earth had the same atmospheric pressure as Mars then water molecules (or Hydrogen and Oxygen atoms that make up water) could easily escape from the atmosphere because Mars has a very low atmospheric pressure and a very small escape velocity (Table 1). This suggests that Earth would lose some of its water to space in the same way that Mars did if Earth was located in the same place as Mars.

Q4. a) Planets in our solar system with molten iron in their cores have magnetic fields surrounding them. Examine this video and explain the role of the magnetic fields in the video.

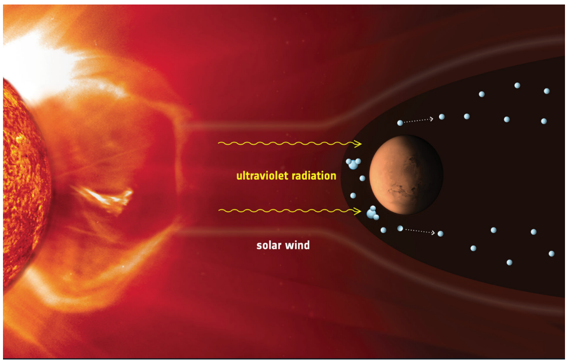
Expected Responses:

- Mars: The Sun is emitting plasma as solar wind and this is streaming past the planet, it looks like it might be hitting Mars or going very close to it.
- Earth: The solar wind doesn't get very close to Earth because there appears to be a shield around it. The shield looks like it's bending and moving as the solar wind impacts it.
- Jupiter: The solar wind doesn't appear to change very much, Jupiter is protected by a larger shield than Earth that only moves a little when the solar wind impacts it.
- The shield is a magnetic field called a magnetosphere that surrounds Earth and Jupiter.

Q4. b) Mars does not have a permanent magnetic field - how do you think this might impact the Martian atmosphere?

Q4. c) What do you think would happen to **Earth's Carbon cycle** if Earth had no magnetic field?

Image Source: ESA Mars Image



Expected Responses:

- Q4 b). I know plasma is very hot and made up of charged gas particles. If these particles are colliding with the molecules in the atmosphere of Mars then they could give energy to these molecules and allow them to reach escape velocity. The molecules could then escape Mars' thin atmosphere.
- Q4 c) If Earth had no magnetic field then the plasma would reach the atmosphere and give the molecules energy to escape, just like what happens on Mars. This would affect the carbon cycle because lots of the CO_2 molecules would escape to space instead of being absorbed by the carbon sinks on Earth. This would also make the planet cooler and maybe help prevent catastrophic climate change. However, if Earth kept losing all its carbon then plant life would die out. (Link to Rich Task 2 Activity 2)

Q5. Using your observations in Q1 - Q4, fill Table 3 with the **similarities and differences** that you have identified between Earth and Mars.

Table 3.

Similarities	Differences
Expected Responses: - Both planets orbit the Sun and are located in the Milky Way galaxy. - Both are classified as rocky planets and have Iron and Nickel cores. - There is water on both planets (although in different forms). - Both planets have carbon. - Both planets have an atmosphere.	Expected Responses: - Earth is located 1 AU from the Sun while Mars is a distance of 1.52 AU from the Sun. - Water on Mars is absorbed in the clay and rocks in the crust so it does not have the same Water Cycle as Earth. - Mars has an atmosphere that is mostly CO_2 but Earth has mostly Oxygen and Nitrogen gases in its atmosphere. - Mars loses most of its carbon to space meaning that it has a different carbon cycle than that on Earth. - Mars has a very thin atmosphere, low atmospheric pressure, small escape velocity and a lower gravitational pull than Earth. - Mars does not have a permanent magnetic field (magnetosphere) so solar wind particles constantly bombard its atmosphere but Earth has a magnetosphere that protects the atmosphere from excessive amounts of solar wind plasma. (When plasma does penetrate our magnetic field we see aurorae). - Mars has a mass that is nine times smaller than Earth's mass. - The Daytime Mean Surface Temperature of Mars is 250K but on Earth it is 290K. - Objects weigh less on Mars than Earth (about twice as much on Earth compared to Mars).