MULTIPLE CHOICE QUESTIONS – 1 MARK UNLESS INDICATED OTHERWISE

TRUE/FALSE QUESTIONS – 0.25 MARK

Imagine it is sometime in the future, several hundred years from now, and humans are colonising the solar system and even other star systems thanks to major improvements in technology including the invention of the Epstein Drive ….

Roxanne Stone, well known areologist* and geologist, returned to Mars as the leader of *Expedition Jezero.* She is joined by several colleagues, many of whom went to school with her or she has known and worked with previously. Team members include:

- Andy Syght (volcanologist),
- Ellie Mints (geochemist),
- Gabi Roe (igneous petrologist),
- Jean Luc Bringuebaler (seismologist),
- Jiki Nakamura (geochronologist),
- Philip Light (metamorphic petrologist),
- Sandra Shore (sedimentologist),
- Rose Kortz (mineralogist),
- Traci Menandai (palaeontologist) and
- Zoe Guāng (astronomer & astrobiologist)

The team met, prior to departing for Mars from Moon Base Alpha, a scientific research station on Earth's Moon not far from Tycho City. Here they discussed *Expedition Jezero* and planned operations. In addition to the team member's expertise, they had access to many other Earth-based and Mars-based colleagues and their expertise to assist their planning and day-to-day operations.
At their first meeting Roxanne addressed the main purpose of the expedition. She explained…

… way back in 2021, NASA landed the Perseverance rover on Mars - in Jezero Crater (see the maps provided). Perseverance collected a wealth of analytical data and imagery during its operation that proved very helpful in planning the human colonisation of Mars. However, Jezero Crate was declared a Special Heritage Site (SHS) prior to colonisation – making it a no-go zone for colonists in order to preserve the site for future research. An SHS declaration also makes it. part of the Interplanetary Museum of Human Endeavour (IMHE). Our mission, the first of its kind, is to ground truth the discoveries made by Perseverance and to ensure Jezero Crater's scientific and cultural heritage is intact.

1. The whole team studied the maps, keen to get on with the mission.
   Q: Are you ready to do the same? **(1 mark – both answers are correct!)**

   a. Yes, let's do it!

*Areology: the study of Mars, its planetary geology plus everything else that makes Mars what it is: a rocky planet with some Earth-like and some not so Earth-like characteristics.

b. No, but let's do it anyway!

2. Studying the Topographic map of Mars (see: data and definitions, page 12) the team first explored the amazing geography of Mars to get more familiar with the landscape. Everyone was amazed to discover the topographic extremes found on the planet.

   Andy's young son, Ooutta, was holidaying on Luna with the rest of the Syght family. He came to the first briefing with Andy because he was too small to wear a Luna trekking space suit and the rest of the family had gone for a walk along the Sting Trail to Picard Crater. He was keen to know how many dinosaurs and active volcanoes are on Mars. Andy explained that we have not found macroscopic life on Mars or seen active volcanism on Mars, but some of the volcanoes are relatively young and may still be active. However, to keep Ooutta happy he added that all of the tallest mountains on Mars were volcanoes.

   Q: How many volcanoes did he say were taller than 12 km above the baseline? (1 mark)

   a. Three
   b. Four
   c. Five
   d. Seven
   e. Fifteen
   f. He didn't give a number because Ooutta isn't old enough to count over 100.

3. Andy also explained that the tallest mountain on Mars, Olympus Mons, is the largest volcano in the solar system. Its highest point is 21 km above the baseline, it started forming 4 km below the baseline and it has a central caldera complex that is 3.2 km deep and between 72 and 91 km in width. The entire volcano is 624 km in width and covers a vast area. He also said that it has slopes of between 4 and 5 degrees, adding that it is a … **(1 mark)**

   a. …stratovolcano
   b. …shield volcano
   c. …cinder cone
   d. …cryovolcano
   e. …rift valley
   f. …a type of volcano not seen on Earth

4. Ooutta was amazed when Andy showed him a topographic map of Hawaii (Figure 1) for comparison after Ooutta claimed that the Big Island volcano, Mauna Kea, must be taller than Olympus Mons because the Big Island grew from the deep ocean floor. Andy pointed out sea level is Earth's equivalent of Martian zero baseline, so to make a fair comparison you must include the below-baseline height of Olympus Mons if you are considering the Big Island's submarine height.

Q: What did Oouta discover after he compared all the information available to him? (1 mark)

a. Despite Mauna Kea being the tallest mountain on Earth, Olympus Mons is 2.5 times taller and about 5 times wider.
b. Despite Mauna Kea being the tallest mountain on Earth, Olympus Mons is 1.5 times taller and about 5 times wider.
c. Despite Mauna Kea being the tallest mountain on Earth, Olympus Mons is 2.5 times taller and about 3 times wider.
d. Despite Olympus Mons being the tallest mountain on Mars, Mauna Kea is 2.5 times taller and about 5 times wider.
e. Despite Olympus Mons being the tallest mountain on Mars, Mauna Kea is 2.5 times taller and about 3 times wider.
f. Mauna Kea is the tallest mountain on Earth and Olympus Mons is the tallest mountain on Mars, but they are about the same size.

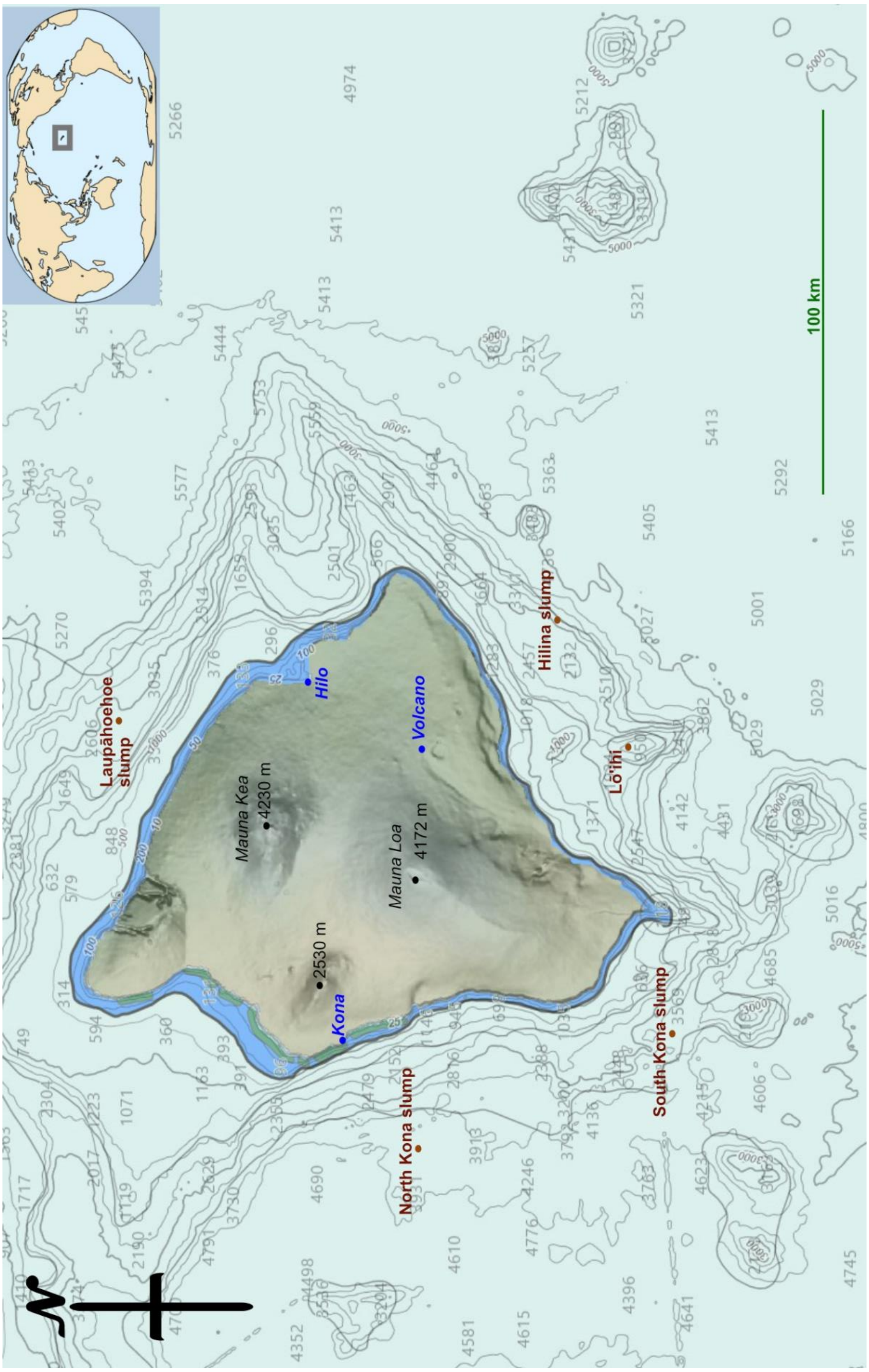


Figure 1: Big Island, Hawaii. Mauna Loa and Mauna Kea, both volcanos, are the two highest peaks on the island. Hilo is the capital. Volcano is a village perched on the edge of Kilauea Crater and is a great place to get married. Kona is a popular tourist destination. Lo'ihi is an actively erupting seamount that is about 400,000 years old. Major off-shore slumps are marked. Slumps are pieces of the island slowly creeping downwards into the abyss. The ocean's abyss adjacent to the Hawaiian Islands has an average depth of 5,500m. Off-shore bathymetry and spot depths are in metres.

Image and image data courtesy of NOAA.

5. The team was listening in and Gabi couldn't resist asking about the slumps shown on the map (Figure 1). Jean Luc commented that the Big Island is gravitationally unstable on its flanks and large areas known as slumps are slowly creeping downwards into the abyss by as much as 10 cm per year.

   Q: He also added that because the island is sometimes shaken by strong earthquakes …

   (1 mark)

   a. …the slump can exceed the friction coefficient between it and the underlying rock, resulting in rapid movement downwards, displacing large volumes of seawater and causing tsunami.
   b. … the slump can exceed the friction coefficient between it and the underlying rock, resulting in rapid movement downwards, displacing large volumes of seawater but not causing tsunami because it is already underwater.
   c. …the slump can exceed the friction coefficient between it and the underlying rock, resulting in slower movement downwards, reducing the risk of tsunami.
   d. …the slump will stop moving, resulting in permanent accretion of the slump material onto the underlying rock thanks to the dewatering effect of shaking wet sediments.
   e. …slumps will happen elsewhere around the island but the rate of slump movement cannot exceed 10 cm per year.
   f. …it is important to be close to the coastline to watch for sea-level movement that might result from gasses trapped in the sediments bubbling upwards and displacing water on the way.

6. Jean Luc was also curious about the seamount labelled Lō’ihi (Figure 1). Gabi, the intrusive igneous rock specialist explained the seamount was also an active volcano. It began developing as a new hot spot volcano on the seafloor, at about a depth of 4000 m, and its summit is now about 1000 m below sea-level. As a seismologist Jean Luc is interested in tectonic activity. He knew the Pacific Plate is moves North-West at about 10 cm per year so was curious to know what this meant for Lō’ihi.

Q: What did Gabi and Andy agree was the best answer? (1 mark)

a. Given the historical growth rate, Lō’ihi is expected to begin forming an island in about 130,000 years. However, since the plate is moving North-West Lō’ihi‘s activity is expected to increase over time, leading to earlier island emergence.
b. Given the historical growth rate, Lō’ihi is expected to begin forming an island in about 130,000 years. However, since the plate is moving North-West Lō’ihi‘s activity is expected to decrease over time, leading to later island emergence.
c. Given the historical growth rate, Lō’ihi is expected to begin forming an island in about 130,000 years. Plate movement will make no difference to when island emergence begins.
d. Given the historical growth rate, Lō’ihi is expected to begin forming an island in about 400,000 years. However, since the plate is moving North-West Lō’ihi‘s activity is expected to decrease over time, leading to later island emergence.
e. Given the historical growth rate, Lō’ihi is expected to begin forming an island in about 40,000 years. However, since the plate is moving North-West Lō’ihi‘s activity is expected to increase over time, leading to later earlier emergence.
f. Since the plate is moving North-West, Lō’ihi‘s activity is expected to decrease to nothing over time and it will never reach the surface.

7. The team's palaeontologist, Traci, reminisced about a holiday she took on the Big Island with her friend Gayle Snowdon. She had a great time visiting lava flows and exploring lava tubes, but said she was amazed by the climate differences between the coastal cities of Hilo and Kona. She said Hilo and the hinterland is very tropical, warm with lots of rain, but Kona and western coastline landscape is extremely dry. She brought up a map of the Big Island to demonstrate what she meant (Figure 2).

Q: What did Gayle say to Traci to explain this difference? (1 mark)

a. The wind normally blows south to north across the Big Island.
b. The wind normally blows north to south across the Big Island.
c. The wind has no regular direction because of the island's location in the Pacific Ocean.
d. The wind follows the coastline around in a counter-clockwise direction.
e. The wind normally blows west to east across the Big Island.
f. The wind normally blows east to west across the Big Island.

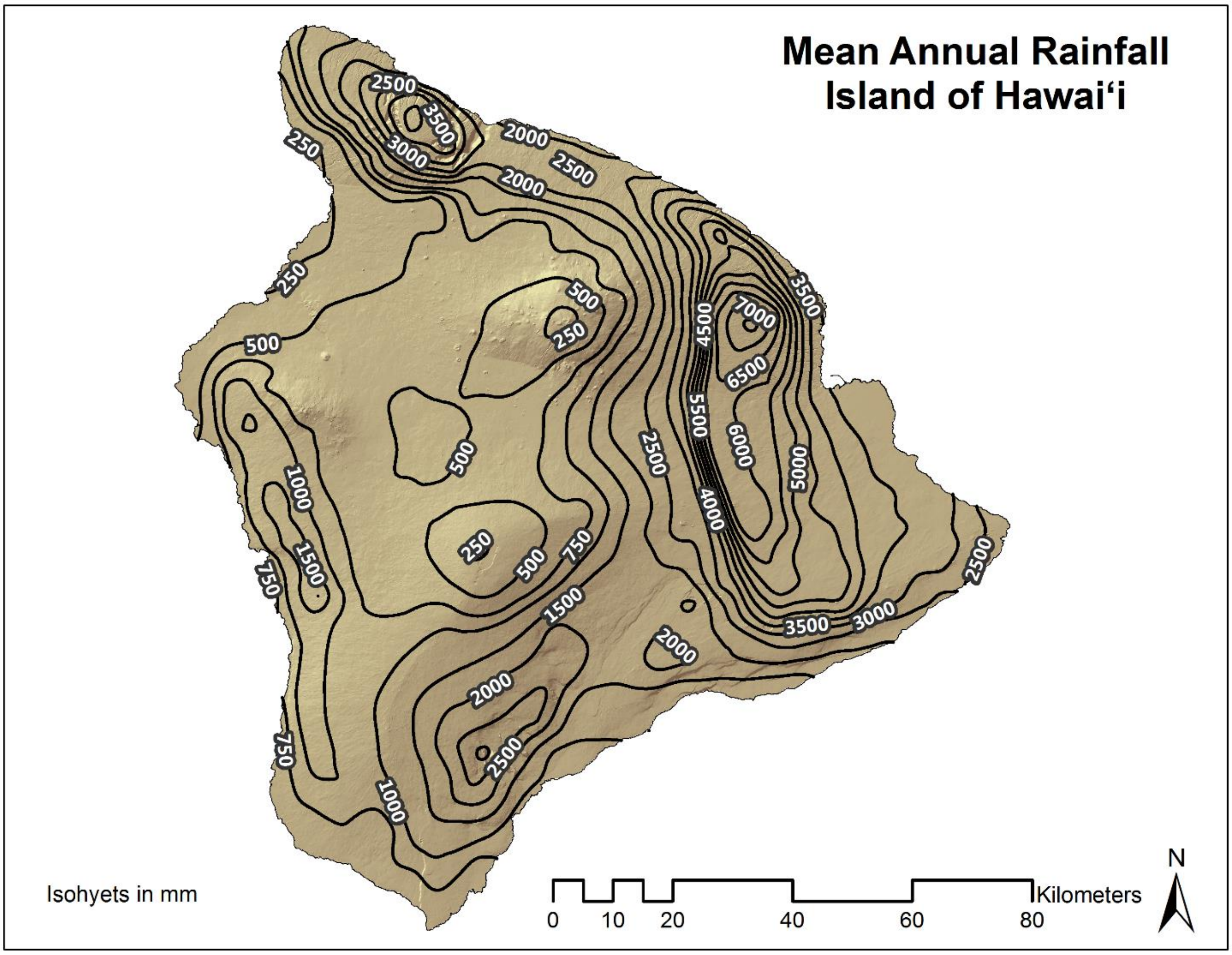


Figure 2: Modified map of the Big Island with rainfall isohyets in mm. Image courtesy of the University of Hawaii.

8. Rose could see that the west coast was very dry, but was puzzled about the figures for Mauna Loa and Mauna Kea (Figure 2). She knew there were astronomical observatories on Mauna Kea, but that it also snowed on the peaks.

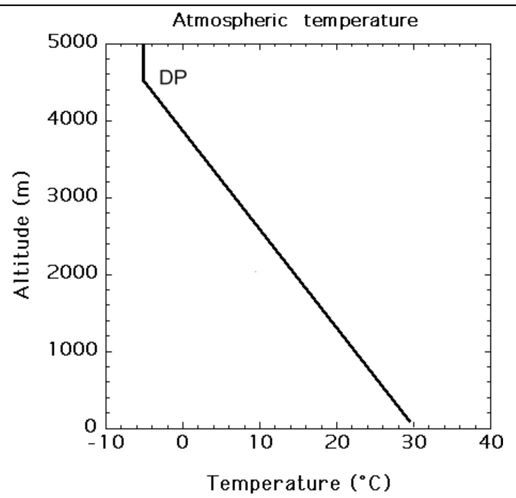
Q: What did Traci say to explain this? (1 mark)

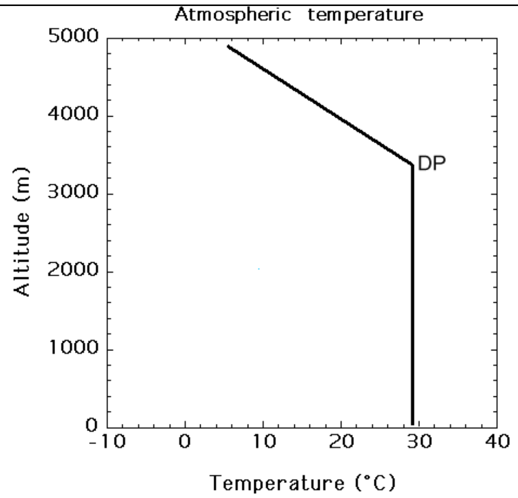
a. The greatest annual rainfall is about halfway up the eastern flanks of Mauna Kea. An inversion layer at this elevation prevents moist air from rising further most of the time.
b. The greatest annual rainfall is about halfway up the western flanks of Mauna Kea. An inversion layer at this elevation prevents moist air from rising further most of the time.
c. The greatest annual is about halfway up the eastern flanks of Mauna Kea. The rising air runs out of moisture before it goes any further upwards.
d. The greatest annual rainfall is about halfway up the western flanks of Mauna Kea. The rising air runs out of moisture before it goes any further upwards.
e. Moisture falling as snow does not get recorded in rain gauges.
f. Moisture rising further upwards is closer to the Sun so is too warm to form clouds and rain.

9. Traci was pleased about how much she remembered from Gayle's 'lessons' as they travelled around the Big Island. When they were in Hilo, the average daily temperature was 30oC, but clouds always obscured their view of Mauna Kea, 80 km away. She always found it odd that when they drove up to visit Zoe at the observatory on Mauna Kea the sky was clear even though the air was very cold.

Q: Which of the six graphs (seen on the next page) did Zoe show her to demonstrate why she couldn't see the mountain top, why it was so cold at the summit and yet so good for astronomy? (1 mark)

Note: For each graph, the black line represents the change in air temperature with altitude. DP marks the elevation of the Dew Point.


Atmospheric temperature
Altitude (m)
Temperature (°C)
DP
5000
4000
3000
2000
1000
0
-10
0
10
20
30
40
a.


Atmospheric temperature
Altitude (m)
Temperature (°C)
DP
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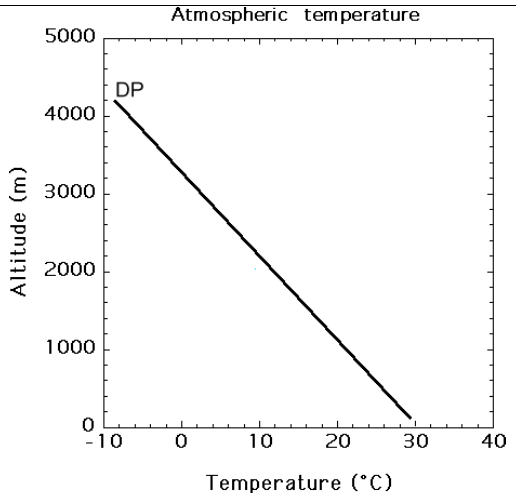
b.


Atmospheric temperature
Altitude (m)
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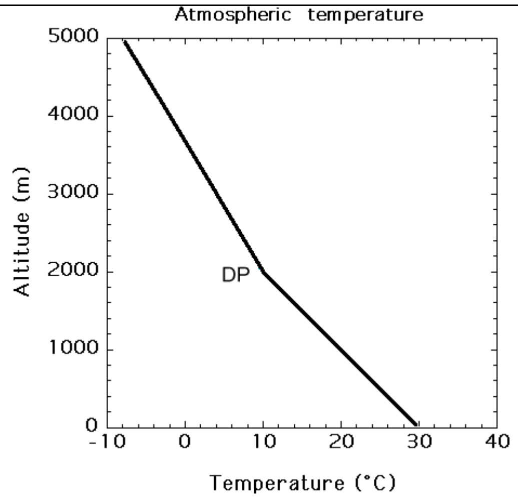
Atmospheric temperature
Altitude (m)
Temperature (°C)
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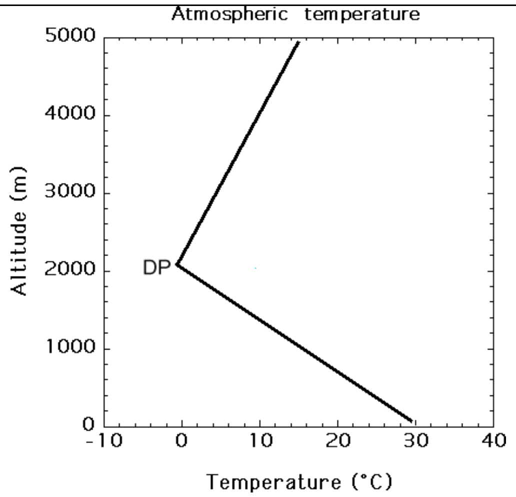
Atmospheric temperature
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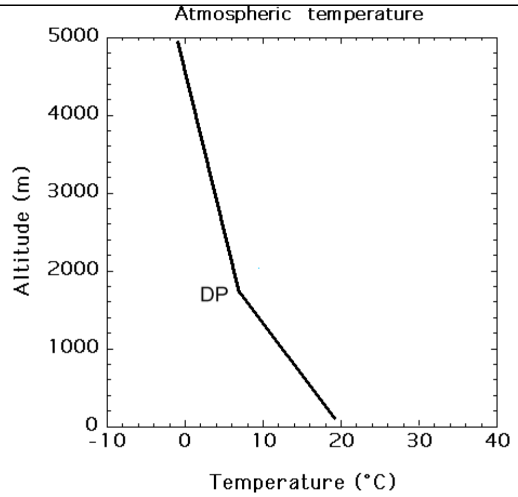
Atmospheric temperature
Altitude (m)
Temperature (°C)
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0
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30
40
f.

Roxanne tried to steer the conversation back to Mars so they could continue planning for Expedition Jezero by asking if anybody knew about the clouds surrounding Mars' tallest mountains. Philip was excited to report that on his last visit to Mars he took the morning tourist in-orbit flight over Arsia Mons which is famous for its morning-only water-ice cloud formation in the Southern Hemisphere spring and summer. He showed them a picture from the brochure (Figure 3)!

Having read up on the details from the scientifically accurate tourist information provided by the guide-bot, Philip was able quiz the team with some true or false questions based on the brochure image (Figure 3).

Q: Which answers, True or False, did Philip know to be correct? Circle the correct answers.

10. Statement: The Martian atmosphere contains enough water vapour at this time of year to form clouds.
    True or False **(0.25 mark)**

11. Statement: At this time of year the Southern Hemisphere atmosphere is warm enough at an altitude of ~45 km to allow water vapour to condense.
    True or False **(0.25 mark)**

12. Statement: The morning wind blows from east to west this time year.
    True or False **(0.25 mark)**

13. Statement: The Southern Hemisphere is warm enough at this time of year to allow water to sublimate from polar ice.
    True or False **(0.25 mark)**

Figure 3: Cloud associated with Arsia Mons streams downwind for ~1500 km each morning during the Southern Hemisphere spring and summer. Clouds form at an altitude of ~45 km. The view is from orbit but looking obliquely down and towards the north. Image is a sample of a larger image, courtesy of ESA/DLR/FU Berlin/J. Cowart, CC

14. Much to Andy's surprise, his daughter Innes called him. They had been forced to abandon their walk to Picard crater shortly after they began the trek due to a solar storm alert. A solar flare had been seen and a coronal mass ejection was heading towards Earth. Ooutta was concerned for his sister but also keen to know more about the storm. Innes explained that a solar storm can cause problems for astronauts, people on the Moon and elsewhere in the solar system, as well as space and satellite communications. She noted that solar storms can have two components; a burst of energy seen as a sudden flash of light and a coronal mass ejection (CME) which is a cloud of magnetised particles thrown out from the sun, but only in a particular direction. She added energetic protons and other particles are very dangerous, they can severely damage electronics but also cause extreme damage to cells, leading to illness and even death. Ooutta knew that the Earth is about 150 million km from the Sun on average and Mars is about 228 million km. Ooutta also knew it took about 8 minutes and 20 seconds for sunlight to reach Earth.

Q: He asked Andy how soon after being seen on the Moon would a person on Mars see the same solar flare. What did Andy correctly say after a quick bit of calculation? (1 mark)

Assuming both Earth and Mars have a line of sight to the source of the flare, …

a. …approximately 12 minutes and 40 seconds.
b. … approximately 8 minutes and 20 seconds.
c. …approximately 6 minutes and 20 seconds.
d. …approximately 4 minutes and 20 seconds.
e. …approximately 2 minutes and 10 seconds.
f. ….it depends if Mars is close to Jupiter which bends light because of its massive gravity.

15. Innes happily added that in 2005 a coronal mass ejection of high-speed protons bombarded Earth as part of a solar storm. In that event, the protons arrived just 30 minutes after the solar flare that was part of the storm was observed. The reasons for such an intense and rapid bombardment might have been special but with solar storm alerts it is best to assume a worst-case scenario and seek shelter. She said they just had enough time to get back to base!

Q: Ooutta exclaimed, *Wow! Just how fast were those protons moving?!* Innes had asked herself the same question and had already worked out the answer which was … (1 mark)

a. …2.76 times the speed of light
b. …the speed of light.
c. …0.651 times the speed of light.
d. …0.556 times the speed of light.
e. …0.278 times the speed of light.
f. …0.217 times the speed of light.