**Thermoregulation in spacesuits**

**Lesson context:** Space exploration demands technological advances that enable survival in extremely harsh environments. Spacesuits are incredible works of engineering, particularly in regard to how they protect astronauts from temperature fluctuations. In this lesson, students will explore contemporary spacesuit design and create their own representation of the suit’s thermoregulation system.

**Target year level/s:** 9 and 10

**Curriculum alignment**

***Science***

Compare the role of body systems in regulating and coordinating the body’s response to a stimulus, and describe the operation of a negative feedback mechanism ([AC9S9U01](https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/science/year-9_year-10/content-description?subject-identifier=SCISCIY9&content-description-code=AC9S9U01&detailed-content-descriptions=0&hide-ccp=0&hide-gc=0&side-by-side=1&strands-start-index=0&subjects-start-index=0&view=quick))

Apply the law of conservation of energy to analyse system efficiency in terms of energy inputs, outputs, transfers and transformations ([AC9S9U05](https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/science/year-9_year-10/content-description?subject-identifier=SCISCIY9&content-description-code=AC9S9U05&detailed-content-descriptions=0&hide-ccp=0&hide-gc=0&side-by-side=1&strands-start-index=0&subjects-start-index=0&view=quick))

Investigate how advances in technologies enable advances in science, and how science has contributed to developments in technologies and engineering ([AC9S9H02](https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/science/year-9_year-10/content-description?subject-identifier=SCISCIY9&content-description-code=AC9S9H02&detailed-content-descriptions=0&hide-ccp=0&hide-gc=0&side-by-side=1&strands-start-index=0&subjects-start-index=0&view=quick))

Write and create texts to communicate ideas, findings and arguments effectively for identified purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate ([AC9S9I08](https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/science/year-9_year-10/content-description?subject-identifier=SCISCIY9&content-description-code=AC9S9I08&detailed-content-descriptions=0&hide-ccp=0&hide-gc=0&side-by-side=1&strands-start-index=0&subjects-start-index=0&view=quick))

***Design and Technologies***

Analyse and make judgements on how the characteristics and properties of materials are combined with force, motion and energy to control engineered systems ([AC9TDE10K03](https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/design-and-technologies/year-9_year-10/content-description?subject-identifier=TECTDEY910&content-description-code=AC9TDE10K03&detailed-content-descriptions=0&hide-ccp=0&hide-gc=0&side-by-side=1&strands-start-index=0&subjects-start-index=0&view=quick))

Analyse and make judgements on how characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions ([AC9TDE10K06](https://v9.australiancurriculum.edu.au/f-10-curriculum/learning-areas/design-and-technologies/year-9_year-10/content-description?subject-identifier=TECTDEY910&content-description-code=AC9TDE10K06&detailed-content-descriptions=0&hide-ccp=0&hide-gc=0&side-by-side=1&strands-start-index=0&subjects-start-index=0&view=quick))

**Learning hook**

Open the lesson by exploring the temperature ranges students have experienced.

Students can find out the annual minimum and maximum temperatures for their locality using [Bureau of Meteorology](https://reg.bom.gov.au/climate/data/stations/) data for the nearest weather station.

Map depicting annual temperature fluctuationAsk students if anyone has experienced greater temperature extremes and discuss where this occurred. The most extreme annual temperature fluctuations on Earth occur at higher latitudes as a result of the difference in day length across the year.

Image created by [Robert A. Rohde](https://commons.wikimedia.org/wiki/User:Dragons_flight) for [Berkeley Earth](http://www.berkeleyearth.org/). Released under Creative Commons by Robert Rohde in his professional capacity as Lead Scientist for Berkeley Earth

With students, discuss the ways humans solve the problem of living in environments with large temperature ranges. Explore the heating and cooling technologies used to maintain habitable living conditions.

**Girls in focus**

An alternative hook for this lesson could be to explore NASA’s [First Woman](https://www.nasa.gov/calliefirst/) graphic novels and interactive, which follow the experiences of Callie, a female astronaut on a lunar base. As a class, explore the human elements of the story before engaging with the STEM components. Discuss the qualities Callie demonstrates in the story. Support students to notice how she responds to challenges and what shapes her decision-making. Use the novels and interactive as a hook to explore the technologies required to support life in space.

**Learning input**

Explain to students that these temperature ranges are nothing compared to the temperature fluctuations on the moon or on Mars.

|  |  |  |
| --- | --- | --- |
| **Planet** | **Minimum surface temperature °F (°C)** | **Maximum surface temperature °F (°C)** |
| Mercury | - 275°F (-170°C) | + 840°F (+ 449°C) |
| Venus | + 870°F (+465°C) | + 870°F (+ 465°C) |
| Earth | - 129°F (- 89°C) | + 136°F (+ 58°C) |
| Moon | - 280°F (- 173°C) | + 260°F (+ 127°C) |
| Mars | - 195°F (- 125°C) | + 70°F (+ 20°C) |

Data sources temperature:

[Mercury: Worldbook at NASA, April 12, 2010.](http://www.nasa.gov/worldbook/mercury_worldbook.html)

[Venus: Worldbook at NASA, April 12, 2010.](http://www.nasa.gov/worldbook/venus_worldbook.html)

[Earth: Global Measured Extremes of Temperature and Precipitation, NOAA, April 12, 2010](http://www.ncdc.noaa.gov/oa/climate/globalextremes.html)

[Moon: Worldbook at NASA, April 12, 2010](http://www.nasa.gov/worldbook/moon_worldbook.html)

[Mars: Worldbook at NASA, April 12, 2010](http://www.nasa.gov/worldbook/mars_worldbook.html)

This means that expeditions and sustained human habitation on the moon, Mars and other planets will require a solution to the challenge of maintaining habitable temperatures in the face of massive temperature fluctuations.

Even the International Space Station experiences a wide range of temperatures. When it faces the Sun, the external temperature is around 121°C, but when Earth blocks the Sun, the external temperature is a very chilly -157°C. On Earth, heat is transferred through the air mainly due to conduction or convection, but in space there is no air, so heat is transferred through thermal radiation. (Source: [ScienceABC](https://www.scienceabc.com/nature/universe/is-it-hot-or-cold-at-the-international-space-station.html))

[](https://www.youtube.com/embed/AwUvh9sluOA?feature=oembed)

As a class, watch [the NASA video](https://www.youtube.com/watch?v=AwUvh9sluOA) explaining spacesuit design. Next, watch [this video](https://www.youtube.com/watch?v=vPkamuLqwM8) explaining the Spacesuit Evaporation Rejection Flight Experiment (SERFE).

[](https://www.youtube.com/embed/vPkamuLqwM8?feature=oembed)

As the class views the video, note key features of the suit and see if students can answer the following questions:

1. Where does transfer of heat occur within and outside the astronaut’s suit?
2. How does the suit achieve cooling and warming?
3. How does the suit determine the need for cooling or warming?
4. What is the impact of changes in gravity?
5. What are the key risks and mitigations associated with the suit?



**Girls in focus**

Girls may not realise the diverse skills and backgrounds of space technology designers.

Share [this article](https://abcnews.go.com/International/prada-design-nasas-new-gen-spacesuits/story?id=103776439) about Prada’s role in designing NASA’s new spacesuits and [this article](https://www.pbs.org/wgbh/nova/article/spacesuit-design-nasa/) about an unconventional pairing of a costume designer and a spacesuit designer that led to the development of a space design firm.

Use these articles as a basis to talk about the creative potential of STEM careers.

**Learning construction**

Students conduct further research into spacesuit thermoregulation technologies. They create a presentation in PowerPoint or Keynote that shows key features of spacesuit temperature maintenance. The presentation must include an animation to show how the thermal control system operates in extreme temperatures.

A list of possible resources is included in the Resources section.

Students must ensure their animation addresses:

* where transfer of heat occurs within and outside the astronaut’s environment
* how cooling and warming occur
* how the suit determines the need for cooling or warming.

The presentation should also address key considerations for design, materials and processes given the use requirements of the suit.

Students should consider how best to communicate the information through their animation and slides to ensure clarity and maximise audience engagement.

**Resources**

Cadogan P (2015) [The past and future space suit](https://www.americanscientist.org/article/the-past-and-future-space-suit). *American Scientist, 103(5).*

Mudawar I (2023) [Heating and cooling space habitats isn’t easy – one engineering team is developing a lighter, more efficient solution](https://theconversation.com/heating-and-cooling-space-habitats-isnt-easy-one-engineering-team-is-developing-a-lighter-more-efficient-solution-211706). *The Conversation.*

NASA (2020) [Spacesuit Evaporation Rejection Flight Experiment (SERFE)](https://www.nasa.gov/image-article/spacesuit-evaporation-rejection-flight-experiment-serfe/).

Stroming JP & Newman DJ (2019) [Critical review of thermal management technologies for portable life support systems](https://ttu-ir.tdl.org/server/api/core/bitstreams/1a31b9db-a5db-4117-b9d2-71e2701d18d8/content).

**Rubric**

|  |  |  |  |
| --- | --- | --- | --- |
| **Criteria** | **Beginning** | **Achieved** | **Exceeded** |
| Heat transfer modelling | Models direct solar radiation to the suit and radiation of body heat to the suit interior. | Models direct solar radiation to the suit; radiation of body heat to the suit interior; and conduction and convection of heat to circulating water/gas. | Models direct solar radiation to the suit; radiation of body heat to the suit interior; and conduction and convection of heat to circulating water/gas. Also models thermal insulation properties of the suit. |
| Considerations given to the use requirements of the suit | Identifies simple use requirements related to astronaut movement and the space environment. | Identifies use requirements related to dynamic astronaut movement and comfort, the space environment and mission length. | Identifies use requirements related to dynamic astronaut movement and comfort, the space environment, mission length and unexpected component failure. |
| Communication | Animation communicates features of the suit, demonstrating selection of some appropriate content, representations, language and text features. | Animation clearly communicates operation of key features of the suit, including appropriate use of content, representations, language and text features. | Animation communicates operation of key features of the suit effectively and in an engaging way, including selection of appropriate content, representations, language and text features. |