Science and Technology Facilities Council

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Thermal Engineering

Is space hot or cold?

Some areas of space are really hot! Gas between stars can appear to be empty space but can actually be thousands (or even millions) of degrees.

However, there is also what is known as the cosmic background temperature, which is minus 270 degrees Celsius - almost, but not quite, absolute zero.

Heat & Temperature - are they the same thing?

Why are there are such huge temperature differences in space? Let’s talk about heat. Often heat and temperature are used as interchangeable terms, but they are NOT the same!

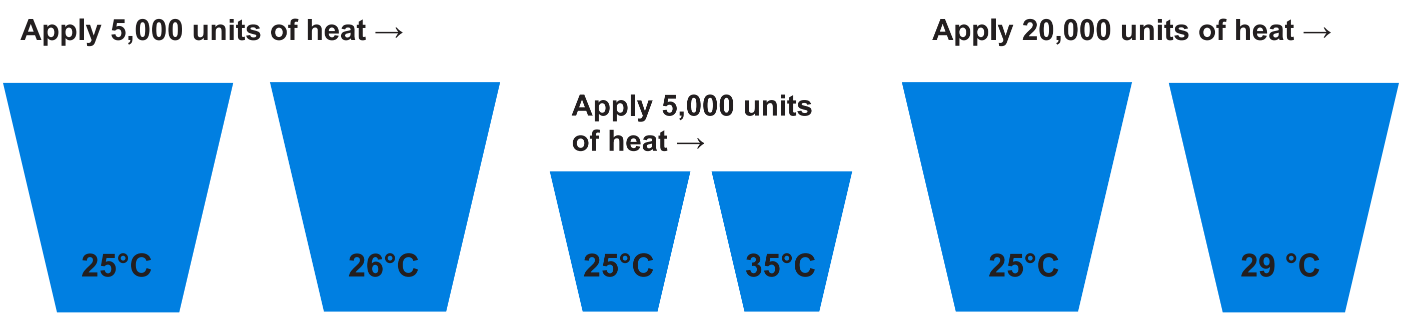
Select the correct answer:

1. Heat is a form of:
    a) Radiation
    b) Energy
    c) Light

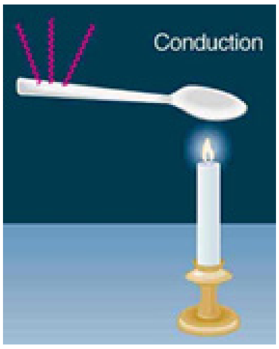
2. Heat is measured in:
    a) Kelvin
    b) Joules
    c) Calories

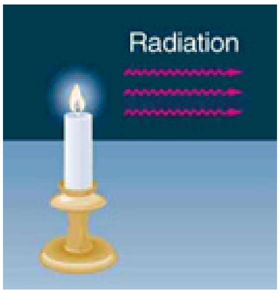
3. Temperature is a measure of how ___________ a substance is and is calculated as the ___________ of particles moving in it.
    a) Hard or soft, density
    b) Dark or light, speed
    c) Hot or cold, speed

The temperature that a substance reaches depends on both the amount (the mass) of substance and the amount of heat you apply to it. For example, if you had a bucket and a cup of water, both at 25°C, and applied the same amount of heat to both, then the cup of water would have a higher temperature than the bucket of water.



Heat can be transferred in three different ways.





Select the correct answer:

4. Conduction is the transfer of energy between objects:

In physical contact | In close proximity | Immersed in water

5. Convection is the transfer fo energy between an object and its environment due to:

Electromagnetic waves | Kinetic energy | Fluid motion

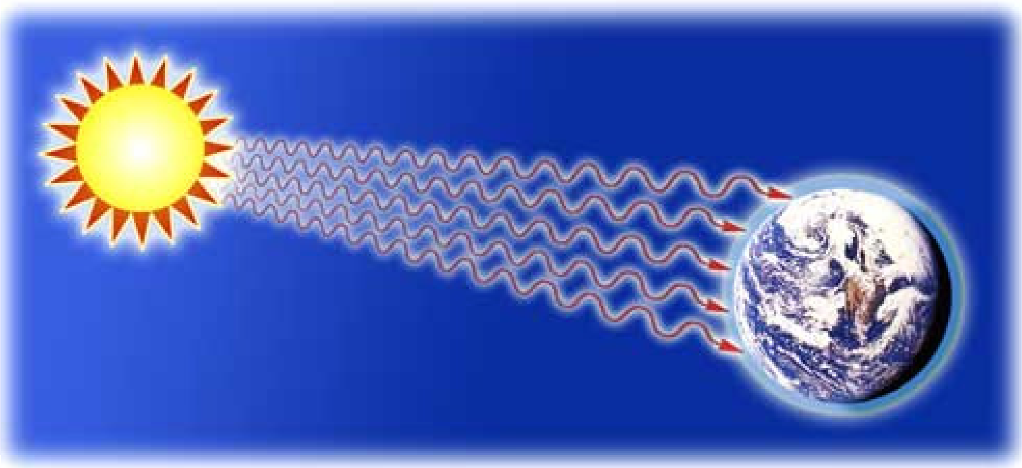
6. Radiation is the transfer of energy by:

Magnetic fields | Electromagnetic waves | Objects in physical contact

How is heat transferred in space?

Space is a vacuum with approximately one atom per cubic centimetre (which isn't a lot!). Because of this, conduction and convection across space are almost entirely non-existent.

Heat from the Sun travels to Earth via radiation.



Space Telescopes

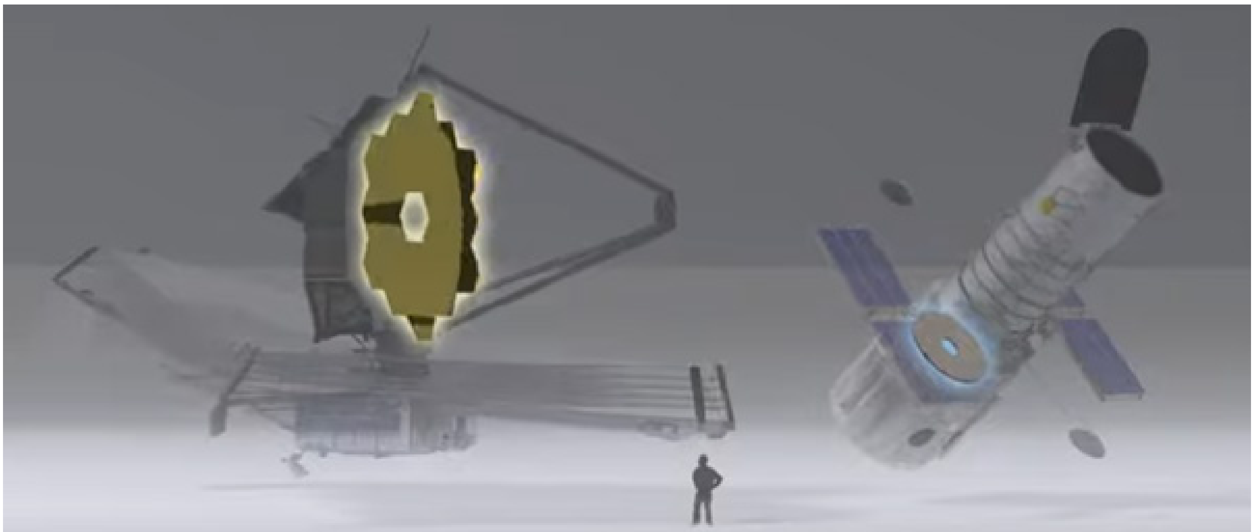
There are so many wonderful photographs of planets, stars, galaxies and nebulas, the vast majority taken by the Hubble Space Telescope.

Hubble was launched in April 1990 and, 30 years later, it is still sending back amazing pictures of the Universe.

Technology has moved on a huge amount since Hubble was launched and soon, NASA will be launching the James Webb Space Telescope (Webb for short), the scientific successor to Hubble. You can find more information about Webb online: jwst.org.uk

Hubble's science pushed scientists to use longer wavelengths of light to "go beyond" what Hubble has already done. Observations of the most distant objects (like the first stars and galaxies formed in the Universe) require an infrared telescope.

Webb has a much bigger mirror than Hubble - 6.5m diameter compared to Hubble's 2.4m diameter. This larger light collecting area means that Webb can see much fainter objects than Hubble can, and in much greater detail.



Webb houses four main instruments that will detect light from distant stars and galaxies, and planets orbiting other stars.

- Near-Infrared Camera (NIRCam)
- Near-Infrared Spectrograph (NIRSpec)
- Mid-Infrared Instrument (MIRI)
- Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph (FGS/NIRISS)

The Mid-Infrared Instrument (MIRI) was designed, built, and tested by a European group of ten member countries, led by the UK, in partnership with NASA Jet Propulsion Laboratory. The European contribution was led by Dr Gillian Wright from the Science and Technology Facilities Council (STFC), and a large portion of the design of the optical camera and the thermal protection was done by STFC scientists and engineers. The whole MIRI instrument was then tested in both the thermal vacuum chamber and in the vibrational test facility at the STFC Rutherford Appleton Laboratory to ensure that it would survive the launch and work perfectly in the harsh environment of space.

Multi-Layer Insulation

Multi-Layer Insulation or MLI is the name given to the shiny thermal insulation that you see on spacecraft.

MLI is specially designed and tailored insulation to keep instruments from freezing in space. It protects detectors and cameras from the heat produced from the spacecraft itself, as well as environmental heat sources such as the Sun.

MLI is made up of several layers of insulating foil and very thin netting and it is extremely lightweight and easy to shape – every gram costs around £16 to send into space in fuel alone, so it's important to make the insulation as light as possible.

The foil and netting design is hugely effective, making thin gaps in between the foils where the netting doesn't allow it to touch – preventing heat from being conducted from one layer to another. There is no air in space so heat can't convect between the layers, and the surfaces are shiny to restrict the amount of heat that is radiated.

Your Challenge!

An instrument taking pictures of the Universe in infrared needs to make sure that it shields its detectors from any heat signals that may interfere with the images. All spacecraft are well insulated, whether to protect the steering mechanisms and communication systems from the extreme cold of space, or whether it is protecting the detectors from the heat produced from the electronics on board.

Try this thermal engineering challenge to make your own MLI and find out how many layers of insulation works best for preventing heat transfer.

You will need:

- Three ice cubes
- Aluminium foil
- Netting (from a pack of oranges or other fruit)
- A heat source e.g. a bright lamp

Share photos of your experiment with us by email visitral@stfc.ac.uk or on social media using #STFCScienceAtHome

1. Wrap one ice cube in one piece of foil - this acts like single layer insulation.
2. Wrap another ice cube in alternating layers of netting and foil, three of each. Repeat for the last ice cube with five of each layer.
3. Leave the ice cubes under a heat source for 5 - 10 minutes.
4. Unwrap the ice cubes and record your observations.
5. Experiment with different numbers of layers, or even different materials to find out what works best.

Use this page to predict what will happen to each ice cube and record your observations.

If you need a hint to get started, watch our video that explains how to make thermal space blankets (MLI) at home: https://youtu.be/dqbY2_vL3RI