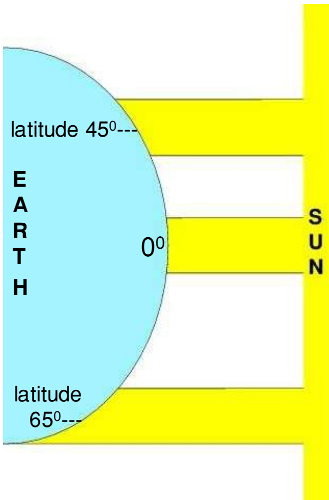
Hot or not?
Investigating how latitude affects the amount of solar radiation received

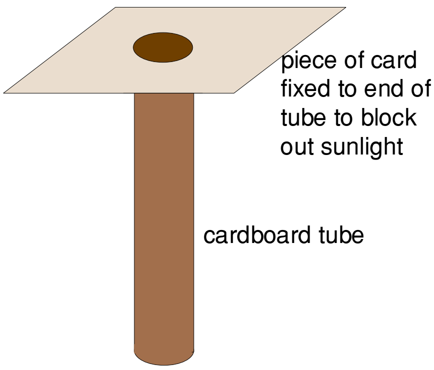
Ask the pupils to think about a cloudless summer's day. Using a globe ask them where it will be hottest and where it will it be coldest at these three latitudes:

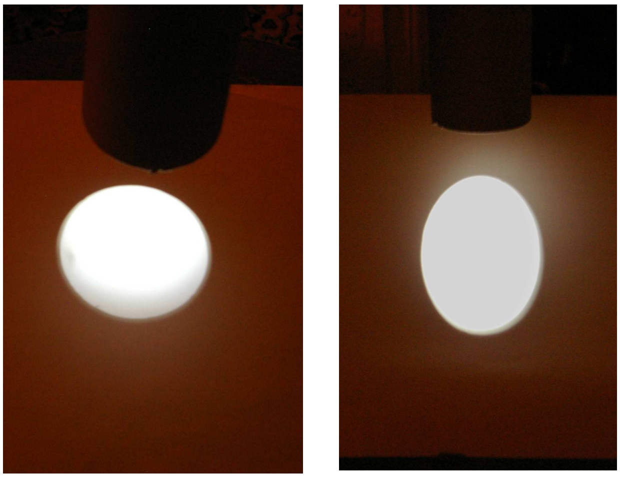
- at the Equator *(most will say hottest here)*
- at 45^0 N (or S)
- at 60^0 N (or S) *(most will say coldest here)*

Explain that the temperature depends on the intensity of the sun's rays (solar radiation) and the position of the tilted Earth relative to the Sun. Show the pupils a copy of the diagram below. They may need to be reminded of the enormous size of the Sun compared to Earth, as demonstrated in the Earthlearningidea 'Playground planets'.



Shine a torch down a vertical, hollow cylinder, e.g. a cardboard tube or drainpipe, on to a flat piece of card, as shown in the left photo opposite. Ask the pupils to describe the shape of the light they see.
Next fix the card at an angle, for example at 45^0, and shine the torch down the vertical tube in the same way as before. Ask the pupils to describe the shape they see. Do they think the light is as intense (bright) when the paper is at an angle as it was when the paper was flat?
If the Sun is shining, this activity works well outside, if a piece of card with a hole in it is fixed to the end of the tube to block out the sun around the cylinder, as shown below.





Torchlight through vertical cardboard tube
Left - on to flat card Right - on to card at 45^0 angle

Photos: Elizabeth Devon

Ask the pupils to:-

- compare the shape and light intensity of the illuminated area on the flat card with that on the card fixed at an angle;
- say which illuminated area demonstrates that the Sun's rays will be more concentrated and so the hotter?
- suggest the dates when the Sun is apparently directly overhead at the Equator so that places on the Equator will be the hottest;
  It is apparently directly overhead at the equinoxes, March 21st and September 21st.
- explain why, in the Northern Hemisphere, the Sun feels hotter in June than in December?
  The Sun is apparently over the Tropic of Cancer on June 21st (summer solstice) and over the Tropic of Capricorn on December 21st (winter solstice) so its rays are more intense in June than in December.
- suggest factors, other than the intensity of the Sun's rays which might affect the temperature at the surface of the Earth.
  Altitude, cloud cover, vegetation, urban areas, land versus sea areas, prevailing winds are some examples.

The back up

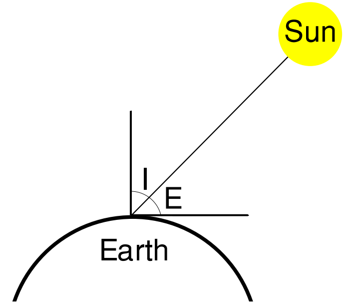


Diagram showing angle of incidence (I) and angle of elevation (E)

Title: Hot or not?

Subtitle: Investigating how latitude affects the amount of solar radiation received.

Topic: This activity could be used in science or geography lessons dealing with the seasons

Age range of pupils: 10 -14 years

Time needed to complete activity: 15 minutes

Pupil learning outcomes: Pupils can:
- explain that the rays of the Sun will be most intense and so the surface of the Earth will be hottest when the Sun's rays apparently come from directly overhead;
- explain that as the Sun's rays move away from overhead, they become less intense because they are spread over a larger area;
- realise that as the tilted Earth moves around the Sun, only twice is the Sun overhead at the Equator, i.e. on March 21st and September 21st;
- realise that the Northern Hemisphere summer occurs when the Sun is overhead at the Tropic of Cancer on June 21st and that the Northern Hemisphere winter when the Sun is overhead at the Tropic of Capricorn on December 21st.

Context:
When the Sun is overhead, as in the torch shining down on to the flat piece of paper, the rays are more intense than when the Sun is not overhead and the rays are reaching the Earth's surface at an angle. For simplicity here, and to help the pupils to remember the dates, all solstices and equinoxes are given as the 21st of the month. In reality the March equinox is usually on 20th March, the June solstice is usually on 20th or 21st June, the September equinox is usually on 22nd or 23rd September and the December solstice is usually on 21st or 22nd December.

Following up the activity:
Pupils could try the Earthlearningideas:
- 'Seasons:- the effect of our tilted Earth'
- 'Earth on Earth: using a globe in the sunshine to show how day/night and the seasons work'.

Underlying principles:
- Changes in the elevation of the Sun relative to the Earth have a direct effect on the intensity of solar radiation or insolation.
- The intensity of solar radiation (insolation) is largely a function of the angle of incidence (I), at which the Sun's rays strike the Earth's surface, measured in degrees away from the normal. An observer on the Earth sees the sun at an angle of elevation (E) measured in degrees above the horizontal. From the diagram, $I = 90 - E$
A high angle of incidence (low angle of elevation) causes a quantity of radiation to be received over a larger surface area than at a low angle of incidence (high elevation).
- The effect of the angle of incidence on insolation intensity can be modelled by a simple equation: local intensity $S = S_0 \times \cos(I)$
where S_0 is the intensity of insolation when the Sun is directly overhead and I is the local angle of incidence. This can also be expressed identically as local intensity $S = S_0 \times \sin(E)$ where E is the local angle of elevation.
- Local solar intensity is also modified by absorption and diffraction within the atmosphere. These effects are not modelled here.
- Earth's seasons are largely controlled by changes in the duration and intensity of solar radiation and both of these factors are governed by the annual change in the position of the Earth's axis relative to the Sun.

Thinking skill development:
By recognising that places near the Equator are always hotter than those near the poles, pupils are establishing a pattern. Factors other than solar radiation can affect surface temperature; this causes cognitive conflict. Discussion involves metacognition and relating the torch light and the angle of the paper to the Sun's rays and the Earth's surface involve bridging skills.

Resource list:
- any hollow cylinder, e.g. a cardboard tube or a drainpipe about 50cm long and 5 to 10cm diameter bore
- torch or other light source (to fit inside tube) or add blocking sheet to the cylinder as shown
- large (A3) piece of card to receive the image
- protractor and books to create the angle
- globe

Source: Written by Elizabeth of the Earthlearningidea team, based on an idea by Martin Devon.

Earthlearningidea	**Strategies and skills developed**
A screaming roller coaster: how fast am I travelling (due to Earth's spin and Earth's orbit)?	A quick 'starter' to remind pupils that the 'stable' Earth on which they live is in fact spinning in space (while orbiting the Sun).
Hot or not? Investigating how latitude affects the amount of solar radiation received	An activity to help pupils to visualise why solar radiation is more intense in equatorial regions than polar ones, involving abstract thinking to relate the activity to the Earth, together with construction and metacognition skills.
The seasons: an indoor demonstration of the seasons	An indoor activity to enable pupils to understand how the tilt of the Earth affects the seasons throughout the year, involving skills of construction and bridging to the real situation.
Earth on Earth: using a globe in the sunshine to show how day/night and the seasons work	A model Earth in the real sunlight brings the abstract nature of day/night and the seasons into a more concrete understanding, allowing the development of three dimensional skills and the use of construction, metacognition and bridging skills.