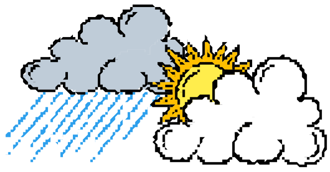
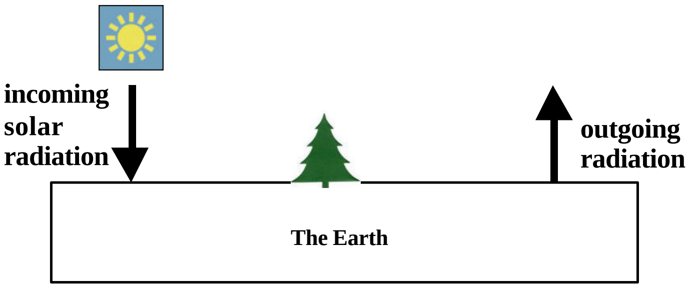
Climate



Data Sheet

At the most fundamental level, the temperature of the Earth is governed by the difference between the amount of ***energy*** the Earth receives from the Sun, and the amount of energy the Earth loses to space.



The ***outgoing radiation*** depends only on the temperature of the Earth, T°K.
The amount of outgoing radiation is given by the Stefan-Boltzman Law:

Outgoing radiation = óT^4 where **ó = 5.67 ´ 10^{-8}** Js^{-1}m^{-2}K^{-4}

Let's start by assuming that the (average) temperature of the Earth's surface is 283°K

The outgoing radiation = óT^4 = 364 Js^{-1}m^{-2} (to 3sf)

This is the energy lost per square metre of the Earth's surface per second.

The ***temperature*** of the Earth depends on the difference between the incoming and outgoing radiation and the heat capacity of the Earth. If the incoming radiation is equal to the outgoing radiation (in this case 364 Js^{-1}m^{-2}) then the temperature of the Earth is constant. If the incoming radiation and outgoing radiation are different, then the temperature of the Earth will change. The following formulae can be applied over successive time increments to predict what will happen to the temperature as time passes.

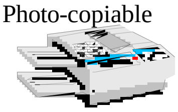
Change in temperature of the Earth

$$= \frac{\textbf{(incoming radiation - outgoing radiation)} \times \textbf{time in seconds}}{\textbf{heat capacity}}$$

where the heat capacity of the Earth = **4 ´ 10^{8}** JK^{-1}m^{-2}

New temperature of the Earth

= old temperature + temperature change



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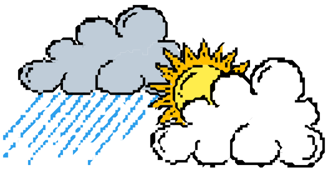


Worksheet

Investigate an increase in incoming radiation
What do you think could change the amount of incoming radiation?

Consider the case where the incoming energy increases by 5% and then remains constant.

Now incoming energy = 1.05 × 364 = ______ $Js^{-1}m^{-2}$

Use the formulae on the Data Sheet to complete the table for this new situation:

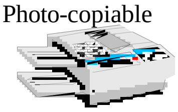
Time *x* (years)	Incoming radiation ($Js^{-1}m^{-2}$)	Outgoing radiation ($Js^{-1}m^{-2}$)	Change in temperature (°K)	Temperature of Earth *y* (°K)
0	364	364	-	283
1	382.2			
2	382.2			
3	382.2			
4	382.2			
5	382.2			
6	382.2			
7	382.2			
8	382.2			

Plot a graph of temperature against time on your graphic calculator.

Describe what happens to the temperature of the Earth.

Find a polynomial function to model the temperature data
To do this, select a quadratic (X^2), cubic (X^3) or quartic (X^4) regression line on your graphic calculator.

Compare your model with an exponential model
The temperature data can also be modelled by the function $y = 283 + 3.53(1 - e^{-0.54x})$.
Compare how well the functions (your polynomial function and the exponential function given above) model the situation. Include consideration of how closely each model fits the data and whether or not it gives realistic predictions for later times.



Investigate a decrease in incoming radiation

Consider the case where the incoming energy decreases by 5% and then remains constant.

Now incoming energy = 0.95 × 364 =

Complete the table below for this new situation:

Time (years)	**Incoming radiation ($Js^{-1}m^{-2}$)**	**Outgoing radiation ($Js^{-1}m^{-2}$)**	**Change in temperature (K)**	**Temperature of Earth (K)**
0	364	364	-	283
1				
2				
3				
4				
5				
6				
7				
8				

Plot a graph of temperature against time on your graphic calculator.

Describe what happens to the temperature of the Earth in this case.

Find a polynomial function to model the temperature data

To do this, select a quadratic (X^2), cubic (X^3) or quartic (X^4) regression line on your graphic calculator.

Compare your model with an exponential model

The temperature data can also be modelled by the function $y = 279.45 + 3.55e^{-0.5x}$.

Compare how well the functions (your polynomial function and the exponential function given above) model this situation. Include consideration of how closely each model fits the data and whether or not it gives realistic predictions for later times.

Extension

If you have time, find models for other % increases and decreases.
You could also try using different time increments.