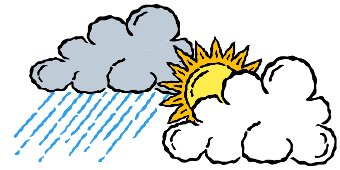
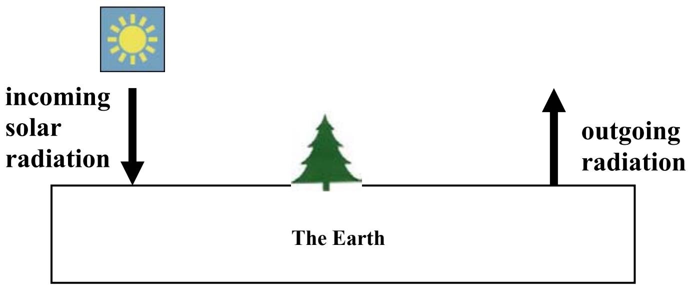
Climate



Data Sheet

The temperature of the Earth depends on the difference between the amount of **energy** the Earth receives from the Sun, and the amount of energy the Earth loses to space. For the Earth's average temperature to be steady, energy must leave at the same rate as it arrives. If energy arrives faster than it leaves, the Earth's temperature will rise.



The rate at which the Earth radiates energy back into space depends only on the temperature of the Earth, and is given by the Stefan-Boltzmann Law:

rate of outgoing radiation per square metre = σT^4

where σ **= 5.67 x** 10^{-8} $\mathbf{Js^{-1}m^{-2}K^{-4}}$ (the Stefan-Boltzmann constant)

The (average) temperature of the Earth's surface is 283 K, and so the energy lost per square metre of the Earth's surface per second is:

Outgoing radiation = $\sigma T^4 = 364\ Js^{-1}m^{-2}$ (to 3sf)

The *change* in temperature of the Earth depends on the difference between the rate at which radiation arrives and the rate at which it leaves. It also depends on the heat capacity of the Earth (how easily the Earth heats up).

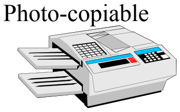
The heat capacity of the Earth = $\mathbf{4 \times 10^8\ JK^{-1}m^{-2}}$; i.e. it takes 4×10^8 J to raise the temperature of 1 m^2 by 1 K.

The change in temperature of the Earth over one year is given by:

temperature change = (incoming radiation – outgoing radiation) × time / heat capacity

and the temperature of the Earth after one year will be given by:

new temperature = old temperature + temperature change



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 = $1.05 \times 364 =$ ______ $\text{Js}^{-1}\text{m}^{-2}$

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

Time x (years)	**Incoming radiation ($\text{Js}^{-1}\text{m}^{-2}$)**	**Outgoing radiation ($\text{Js}^{-1}\text{m}^{-2}$)**	**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 $y = 283 + 3.53\left(1 - e^{-0.54x}\right)$.
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.

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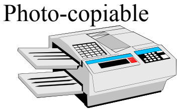

Investigate a decrease in incoming radiation

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.