Lesson 5: Final Planet Details
Time: approximately 40 minutes
Materials: Text: Final Planet Details (from web site – 1 per group)

Overview

Students finalize the values of MASS, DISTANCE, BOND ALBEDO and GREENHOUSE EFFECT for their planets and determine their planet’s average surface temperature. Students then assess whether their planet is likely to have liquid water based on its average surface temperature and decide where on their planet they should look to find life.

Purpose

This lesson teaches that there are many factors that affect the temperature and habitability of a planet and that the search for life on a planet is not necessarily restricted to planets lying within a “habitable zone.”

Standards

A complete list of the standards covered by this lesson is included in the Appendix at the end of the lesson.

Procedure

The groups should read the Lesson 5: Final Planet Details and enter their selected values into the Planet Temperature Calculator. They should start with the values they selected for MASS in Lesson 2, BOND ALBEDO in Lesson 3 and for GREENHOUSE EFFECT in Lesson 4. They may change these values if they want, but they must stay within the ranges dictated by their choices on the Planet Preference Survey. Groups should have access to the Survey and these earlier lessons. After putting these values into the Temperature Calculator, the groups will have an average surface temperature for their planet.

You have been traveling through space for many years at close to the speed of light. For most of those years you and your crewmates have been in a very deep sleep to cut down on the amount of food, air and water you need to survive. Suddenly, your computer wakes you and your crewmates and informs you that your space ship is getting close to the planetary system that you have decided to explore.

Now that you are much closer to your chosen planet you can study it better. Over the next few days your spaceship slowly approaches your nearest star and the planets and moons that orbit it. As you fly near your chosen planet or moon you can take more precise measurements of its BOND ALBEDO, and GREENHOUSE EFFECT, its DISTANCE from the star that it orbits, and the MASS of the star. You will this information into the ship’s computer and get an accurate reading of the planet’s average surface temperature.
It is now time to make the final decision about which planet you plan to explore. Get out the Planet Preference Survey that you filled out when you began this project. The choices that you made on the survey determine the range of values that you can enter in the Planet Temperature Calculator.

Open the Planet Temperature Calculator (http://www.astro.indiana.edu/~gsimonel/temperature1.html). Begin by entering the DISTANCE that you chose on the Planet Preference Survey. Then look back at Lessons 2, 3 and 4. In these lessons you selected values for MASS, BOND ALBEDO and GREENHOUSE EFFECT. Find these values and enter them into the calculator.

You may change these three values if you’d like, but you must stay within the range allowed for the choices you made on the Planet Preference Survey. Here are the allowable ranges, based on what you selected on your Planet Preference Survey:

For MASS:
If you chose “Low mass” enter a number between 0.1 & 0.4
If you chose “Solar type” enter a number between 0.4 & 1.5
If you chose “High mass” enter a number greater than 1.5

Remember that increasing the MASS of the nearest star decreases the life span of the star. Your star cannot be older than its total life cycle.

For DISTANCE you must use the DISTANCE you chose on the planet preference survey.

BOND ALBEDO will depend on the type of surface you chose:
If you chose “Solid, rocky” enter a number between 1 and 15.
If you chose “Solid, ice covered” enter a number between 50 and 80 for a fresh ice covered surface, or between 10 and 50 for an old, dirty ice covered surface.
If you chose “Liquid” enter a number between 15 and 25.
If you chose “Mixture, mostly rock” enter a number between 15 and 40.
If you chose “Mixture, mostly ice” enter a number between 20 and 60.
If you chose “Mixture, mostly liquid” enter a number between 12 and 40.

GREENHOUSE EFFECT will depend on the type of atmosphere you chose:
If you chose “Trace” choose a number between 0 and 0.4.
If you chose “Thin” choose a number between 0.4 and 3.
If you chose “Thick” choose a number between 3 and 300.

Once you have found the average surface temperature, check to make sure your planet’s surface makes sense for that temperature. For example, you
can not have an ice-covered surface if your planet’s average surface temperature is above 0ºC. If you need to, change your planet’s surface to one that can exist at that temperature. Adjust your BOND ALBEDO to fit your new surface and recalculate a new temperature.

1) After you have experimented with different settings, decide which values work best for your planet. Write the final values for your planet below.

**MASS of nearest star:** _______

**DISTANCE from nearest star:** _______

**BOND ALBEDO of planet:** _______

**GREENHOUSE EFFECT of planet:** _______

Enter these values into the planet temperature calculator.

2) What is the average surface temperature of your planet in degrees Celsius?

_______ºC

After finding their average surface temperature, groups will check that the age of their star does not exceed its life cycle. If their star is too old they will need to reduce its MASS to increase its life cycle. This check has already been performed in lesson 2, so the groups should not encounter difficulty here unless they have changed the value of their star’s MASS since that lesson.

3) What is the life cycle of your nearest star?

__________________ years.

4) Look at your original Planet Preference Survey. What is the AGE of your nearest star?

__________________ years.

5) Is the age of your nearest star less than the life cycle of the star?

Yes / No

(If the answer is “No” then you must go back and reduce the MASS of your nearest star until its life cycle is greater than its age.)

Chances are some groups will discover that their planets are not habitable according to the definition of habitability that we have used so far. This next section suggests ways that a planet outside of a habitable zone might still harbor life.
6) Is this planet habitable according to our definition? (Is the average surface temperature between 0 ºC and 100 ºC?)

Yes / No

If you answered “Yes” to question #6:

Congratulations! It looks like your mission is going just fine. You should plan to land on your planet soon and begin exploring it. Remember that your mission is to discover life. This is a good time to discuss your exploration plans with your crewmates. Since the planet is large the crew will divide up and explore different parts of the planet.

Fill out the Mission Update Form on the last page and send it back home to Earth with your original Planet Preference Survey.

If you answered “No” to question #6:

All is not lost. There are still ways life might be able to survive on your planet. Just because a planet’s average surface temperature is below 0ºC or above 100ºC does not mean that water can never exist there as a liquid.

The first suggestion is to look beyond the average surface temperature of a planet to consider the range of temperatures that may be found there. Calculating the expected temperature range of a planet can be very complicated, so in this lesson rough approximations are fine. In coming up with ballpark possibilities, the groups should keep two general principals in mind: 1) the higher the average surface temperature of a planet, the larger the potential range of temperature; and 2) the greater the greenhouse effect of a planet’s atmosphere, the smaller the potential range.

The temperature range is most heavily influenced by the rate of rotation of a planet, which determines the length of a day on that planet, and the degree of tilt of the planet, which determines the nature of the seasons on the planet. Mercury, which has a high average surface temperature and almost no atmosphere, has a temperature range of slightly less than 600ºC (over 1,000ºF). Earth, which has a lower average surface temperature and a somewhat modest greenhouse effect, has a temperature range of around 146ºC (263ºF). Keep in mind that a large greenhouse effect can prevent any change in temperature, which is the case with Venus, whose temperature does not change by more than around 25ºC anywhere on the planet, despite having a slower rate of rotation than Mercury.

Temperatures on a planet can be much higher or lower than the average temperature. If your planet has very long days and nights, then the side of the planet facing the nearest star (the “day” side) heats up while the side facing away (the “night” side) cools down.
Many planets, like Earth, have seasons, so some places will be much warmer in the summer and cooler in the winter. If your planet has an average surface temperature within 50°C of the 0 - 100°C range, then you might have areas of the planet where water can exist as a liquid. However, remember that the greenhouse effect traps heat, which reduces the temperature range. If your greenhouse effect is greater than 3, then this approach may not work for your planet. For an idea of how extreme a temperature range can be on a planet, look at the temperature range of Mercury, which has a very long day/night cycle and almost no atmosphere to trap heat. Compare this with Venus, which has even longer days and nights but almost no change in temperature because of its strong greenhouse effect.

Even if the range of temperatures on a planet does not allow liquid water on the surface, planets may contain liquid water under the surface. Groups should also consider this possibility.

Planets that are too cold to have liquid water at their surface can often have liquid water under their surface. If your planet has a rocky surface you can have water under the ground. Some scientists think Mars has water underground. Underground caves filled with water might be a good place to look for life. Planets with ice-covered surfaces might have liquid oceans under the ice. Scientists think Europa, a moon of Jupiter, has an ice-covered ocean.

Most scientists think liquid water is needed to support any life, but not everyone agrees, and some people try to imagine how life might survive using other liquids or even no liquids at all. You might have a hard time convincing mission control on Earth that it is worth the effort and expense to explore a planet without any liquid water, but it is worth a try. If your crew can imagine a way that life can survive without any liquid water, then it is worth telling mission control your ideas. If you can present a good case then they may approve your mission. Keep in mind, however, that your chances of finding life seem much greater on a planet with liquid water somewhere.

Finally, if groups can not imagine any way that life can exist on their planet, they should be allowed to change any ONE choice from their Planet Preference Survey. Groups should discuss which factor they want to change and input an appropriate value to the Planet Temperature Calculator to determine their planet’s new average surface temperature. Even if a group has a planet in a habitable zone they should be allowed to make this change if they want. Some changes, such as the AGE of their nearest star, may not have an impact of average surface temperature but may affect the type of life discovered on the planet.

If you think your planet or moon is much too hot or cold to support life, then you may have to change your plans. Fortunately, there are a lot of other planets and moons fairly close by, and even a few nearby stars. If you think that there is little hope of finding life on your current planet or moon then you may
explore a different one. However, the new planet or moon must be similar to your original one because that is what your mission has prepared for. Therefore, you may change any ONE choice that you made on your Planet Preference Survey. Discuss with your group which choice you should change and what your new choice is. Then go back and recalculate your new average surface temperature using a value from the new allowable range for that choice. Fill out the Mission Update form on the last page and send it back home to Earth with your original Planet Preference Survey.

Good luck to all explorers!

Once the groups have finalized the physical aspects of their planets they should fill out the Mission Update Forms (Appendix B). If the individual lessons have not been collected and checked up to this point it is a good idea to collect the group folders at this time and check the group’s work thus far for consistency and reasonableness.
Appendix A

Standards Addressed
Benchmarks (Grades 3 through 5)

1B – Scientific Inquiry
Scientific investigations may take many different forms, including observing what things are like or what is happening somewhere, collecting specimens for analysis, and doing experiments. Investigations can focus on physical, biological, and social questions.

2C – Mathematical Inquiry
Numbers and shapes—and operations on them—help to describe and predict things about the world around us.

4A - The Universe
Stars are like the sun, some being smaller and some larger, but so far away that they look like points of light.

4B – The Earth
Like all planets and stars, the earth is approximately spherical in shape. The rotation of the earth on its axis every 24 hours produces the night-and-day cycle. To people on earth, this turning of the planet makes it seem as though the sun, moon, planets, and stars are orbiting the earth once a day.

5D – Interdependence of Life
For any particular environment, some kinds of plants and animals survive well, some survive less well, and some cannot survive at all.

11B – Models
Seeing how a model works after changes are made to it may suggest how the real thing would work if the same were done to it.

12A – Values and Attitudes
Keep records of their investigations and observations and not change the records later.

12D – Communication Skills
Use numerical data in describing and comparing objects and events.

Benchmarks (Grades 6 through 8)

1C – The Scientific Enterprise
Computers have become invaluable in science because they speed up and extend people's ability to collect, store, compile, and analyze data, prepare research reports, and share data and ideas with investigators all over the world.

3A – Technology and Science
Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

4A – The Universe
The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the earth and to behave according to the same physical principles. Unlike the sun, most stars are in systems of two or more stars orbiting around one another.

Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe.

4B – The Earth
The earth is mostly rock. Three-fourths of its surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin blanket of air. It is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the Earth’s.

Because the earth turns daily on an axis that is tilted relative to the plane of the earth's yearly orbit around the sun, sunlight falls more intensely on different parts of the earth during the year. The difference in heating of the earth's surface produces the planet's seasons and weather patterns.

4E – Energy Transformation
Most of what goes on in the universe—from exploding stars and biological growth to the operation of machines and the motion of people— involves some form of energy being transformed into another. Energy in the form of heat is almost always one of the products of an energy transformation.

11B – Models
Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous.

Mathematical models can be displayed on a computer and then modified to see what happens.

11D – Scale
As the complexity of any system increases, gaining an understanding of it depends increasingly on summaries, such as averages and ranges, and on descriptions of typical examples of that system.

Benchmarks (Grades 9 through 12)
1A – The Nature of Science
Scientists assume that the universe is a vast single system in which the basic rules are the same everywhere. The rules may range from very simple to extremely complex, but scientists operate on the belief that the rules can be discovered by careful, systematic study.

2B – Mathematics, Science and Technology
Mathematical modeling aids in technological design by simulating how a proposed system would theoretically behave.

4A – The Universe
Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe.

4B – The Earth
Life is adapted to conditions on the earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of radiation from the sun that allows water to cycle between liquid and vapor.

11B – Models
The basic idea of mathematical modeling is to find a mathematical relationship that behaves in the same ways as the objects or processes under investigation. A mathematical model may give insight about how something really works or may fit observations very well without any intuitive meaning.

Computers have greatly improved the power and use of mathematical models by performing computations that are very long, very complicated, or repetitive. Therefore computers can show the consequences of applying complex rules or of changing the rules. The graphic capabilities of computers make them useful in the design and testing of devices and structures and in the simulation of complicated processes.

National Standards (Grades 5-8)
Understandings about Scientific Inquiry
Mathematics is important in all aspects of scientific inquiry.

Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.

Transfer of Energy
The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Populations and Ecosystems
The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including
Part 2: Build Your Own Planet

Humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.

Earth in the Solar System
The sun is the major source of energy for phenomena on the earth’s surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun’s energy hitting the surface, due to the tilt of the earth's rotation on its axis and the length of the day.

National Standards (Grades 9-12)
Understandings about Scientific Inquiry
Scientists rely on technology to enhance the gathering and manipulation of data. New techniques and tools provide new evidence to guide inquiry and new methods to gather data, thereby contributing to the advance of science. The accuracy and precision of the data, and therefore the quality of the exploration, depends on the technology used.

Energy in the Earth System
Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth’s original formation.

Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Indiana Standards
Grade 5
Mathematics – Measurement
5.5.6 – Compare temperatures in Celsius and Fahrenheit, knowing that the freezing point of water is 0°C and 32°F and that the boiling point is 100°C and 212°F.

Problem Solving
5.7.1 – Analyze problems by identifying relationships, telling relevant from irrelevant information, sequencing and prioritizing information, and observing patterns.

5.7.2 – Decide when and how to break a problem into simpler parts.

5.7.3 – Apply strategies and results from simpler problems to solve more complex problems.

5.7.5 – Recognize the relative advantages of exact and approximate solutions to problems and give answers to a specified degree of accuracy.

5.7.8 – Decide whether a solution is reasonable in the context of the original situation.

Science – Communication Skills
5.2.7 – Read and follow step-by-step instructions when learning new procedures.
Critical Response Skills
5.2.8 – Recognize when and describe that comparisons might not be accurate because some of the conditions are not kept the same.

The Universe
5.3.2 – Observe and describe that stars are like the sun, some being smaller and some being larger, but they are so far away that they look like points of light.

Matter and Energy
5.3.8 – Investigate, observe, and describe that heating and cooling cause changes in the properties of materials, such as water turning into steam by boiling and water turning into ice by freezing. Notice that many kinds of changes occur faster at higher temperatures.

Systems
5.6.1 – Recognize and describe that systems contain objects as well as processes that interact with each other.

Grade 6
Mathematics – Algebra and Functions
6.3.9 – Investigate how a change in one variable relates to a change in a second variable.

Problem Solving
6.7.1 – Analyze problems by identifying relationships, telling relevant from irrelevant information, identifying missing information, sequencing and prioritizing information, and observing patterns.

6.7.3 – Decide when and how to break a problem into simpler parts.

6.7.4 – Apply strategies and results from simpler problems to solve more complex problems.

6.7.6 – Recognize the relative advantages of exact and approximate solutions to problems and give answers to a specified degree of accuracy.

6.7.10 – Decide whether a solution is reasonable in the context of the original situation.

Science – The Scientific Enterprise
6.1.6 – Explain that computers have become invaluable in science because they speed up and extend people’s ability to collect, store, compile, and analyze data; prepare research reports; and share data and ideas with investigators all over the world.

Technology and Science
6.1.7 – Explain that technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.
Computation and Estimation
6.2.2 – Use technology, such as calculators or computer spreadsheets, in analysis of data.

Communication Skills
6.2.5 – Organize information in simple tables and graphs and identify relationships they reveal. Use tables and graphs as examples of evidence for explanations when writing essays or writing about lab work, fieldwork, etc.

6.2.6 – Read simple tables and graphs produced by others and describe in words what they show.

6.2.8 – Analyze and interpret a given set of findings, demonstrating that there may be more than one good way to do so.

The Earth and the Processes that Shape It
6.3.4 – Explain that we live on a planet which appears at present to be the only body in the solar system capable of supporting life.

Matter and Energy
6.3.17 – Recognize and describe that energy is a property of many objects and is associated with heat, light, electricity, mechanical motion, and sound.

Interdependence of Life and Evolution
6.4.10 – Describe how life on Earth depends on energy from the sun.

Models and Scale
6.7.2 – Use models to illustrate processes that happen too slowly, too quickly, or on too small a scale to observe directly, or are too vast to be changed deliberately, or are potentially dangerous.

Grade 7
Mathematics – Problem Solving
7.7.1 – Analyze problems by identifying relationships, telling relevant from irrelevant information, identifying missing information, sequencing and prioritizing information, and observing patterns.

7.7.3 – Decide when and how to break a problem into simpler parts.

7.7.4 – Apply strategies and results from simpler problems to solve more complex problems.

7.7.5 – Make and test conjectures by using inductive reasoning.

7.7.7 – Recognize the relative advantages of exact and approximate solutions to problems and give answers to a specified degree of accuracy.

7.7.11 – Decide whether a solution is reasonable in the context of the original situation.
Science – Matter and Energy

7.3.11 – Explain that the sun loses energy by emitting light. Note that only a tiny fraction of that light reaches Earth. Understand that the sun’s energy arrives as light with a wide range of wavelengths, consisting of visible light and infrared and ultraviolet radiation.

7.3.14 – Explain that energy in the form of heat is almost always one of the products of an energy transformation, such as in the examples of exploding stars, biological growth, the operation of machines, and the motion of people.

7.3.16 – Recognize and explain that different ways of obtaining, transforming, and distributing energy have different environmental consequences.

Grade 8

Mathematics – Problem Solving

8.7.1 – Analyze problems by identifying relationships, telling relevant from irrelevant information, identifying missing information, sequencing and prioritizing information, and observing patterns.

8.7.2 – Make and justify mathematical conjectures based on a general description of a mathematical question or problem.

8.7.3 – Decide when and how to break a problem into simpler parts.

8.7.4 – Apply strategies and results from simpler problems to solve more complex problems.

8.7.5 – Make and test conjectures by using inductive reasoning.

8.7.7 – Recognize the relative advantages of exact and approximate solutions to problems and give answers to a specified degree of accuracy.

8.7.11 – Decide whether a solution is reasonable in the context of the original situation.

Science – Manipulation and Observation

8.2.4 – Use technological devices, such as calculators and computers, to perform calculations.

Communication

8.2.7 – Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions.

The Physical Setting

8.3.14 – Describe how heat can be transferred through materials by the collision of atoms, or across space by radiation, or if the material is fluid, by convection currents that are set up in it that aid the transfer of heat.
Interdependence of Life and Evolution
8.4.8 – *Describe how environmental conditions affect the survival of individual organisms and how entire species may prosper in spite of the poor survivability or bad fortune of individuals.*

Models and Scale
8.7.3 – *Use technology to assist in graphing and with simulations that compute and display results of changing factors in models.*

Earth and Space Science
The Universe
ES.1.3 – *Compare and contrast the differences in size, temperature, and age between our sun and other stars.*

ES.1.8 – *Discuss the role of sophisticated technology, such as telescopes, computers, space probes, and particle accelerators, in making computer simulations and mathematical models in order to form a scientific account of the universe.*

The Earth
ES.1.10 – *Recognize and describe that earth sciences address planet-wide interacting systems, including the oceans, the air, the solid earth, and life on Earth, as well as interactions with the Solar System.*

ES.1.13 – *Explain the importance of heat transfer between and within the atmosphere, land masses, and oceans.*
Appendix B

Copy of Mission Update Form (included with lesson)

Name of Group: ______________________________.

Name of Planet: ______________________________.
(Since you and your crewmates are the first Earthlings to land on the planet, you get to name it!)

Mark your final selections with an “X” and write in the final values that you entered into the planet preference calculator.

1) Type of nearest star:
   ___ Low mass
   ___ Solar type
   ___ High mass
   MASS of nearest star: ________

2) AGE of nearest star: ________ billion years old

3) DISTANCE to nearest star: ________AU

4) Type of surface:
   ___ Solid, rocky
   ___ Solid, ice covered
   ___ Liquid
   ___ Mixture, mostly rock
   ___ Mixture, mostly ice
   ___ Mixture, mostly liquid
   BOND ALBEDO of planet: _______

5) Type of atmosphere:
   ___ Trace
   ___ Thin
   ___ Thick
   GREENHOUSE EFFECT on planet: ______

6) Type of planet:
   ___ Small rocky
   ___ Large rocky
   ___ Moon of a rocky planet
   ___ Moon of a gas giant
   ___ Moon of an ice giant
   ___ Moon of a brown dwarf

Use the Planet Temperature Calculator to fill in lines 7 and 8.
Part 2: Build Your Own Planet

7) Life cycle of nearest star: ________________ years

8) Average surface temperature of the planet: ___________ °C.

9) Describe anything else that affects the surface temperatures on your planet, such as the seasons or the day/night cycle.

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

10) Where are you likely to find liquid water on your planet? ________________

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

11) Check here _____ if you made a change from your Planet Preference Survey. What did you change?

__________________________________________________________________
__________________________________________________________________

12) Describe where on your planet you intend to look for life and why you intend to look there.

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________