Loop Antenna Lesson Plan

Attachment A

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Loop Antenna Lesson Plan Overview (Lesson 1)

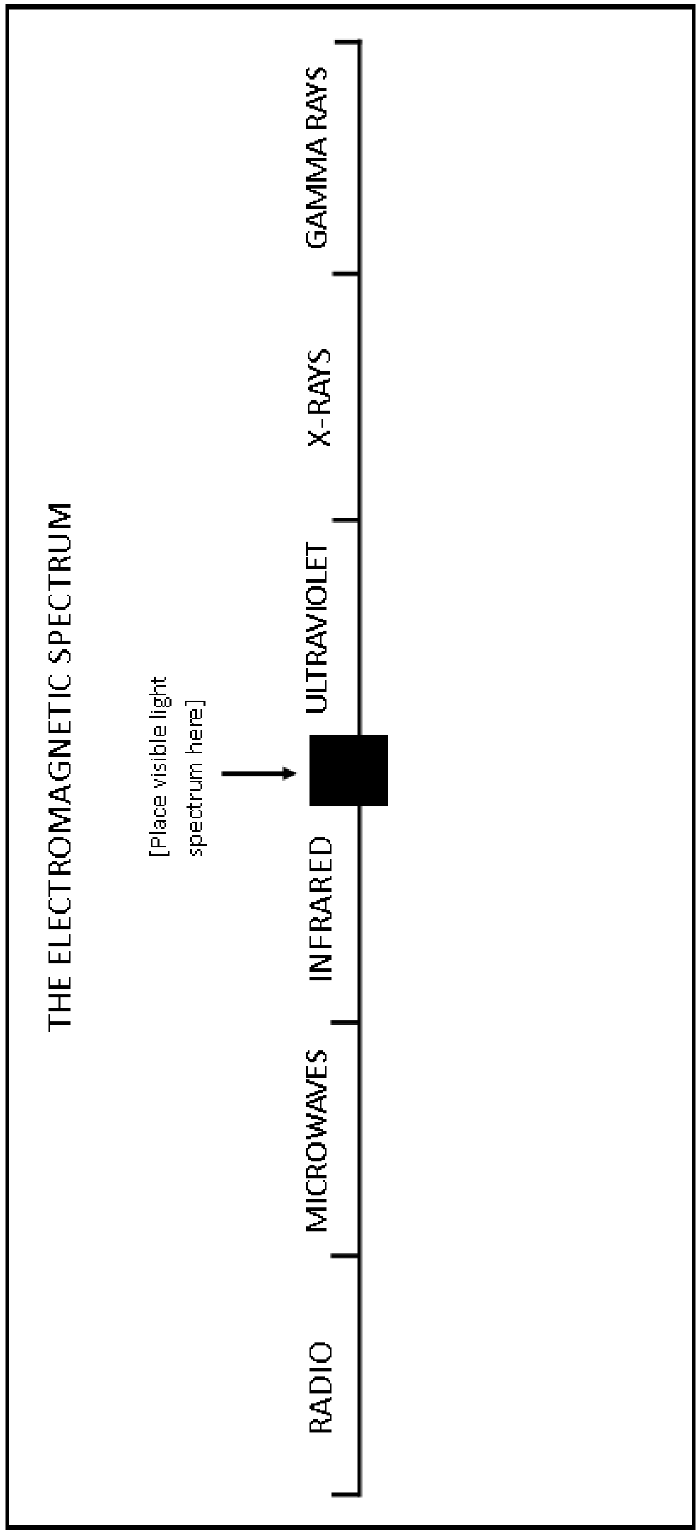
Throughout history, people have looked up at the stars and wondered, "What's out there?" When most people think of astronomy, they picture someone looking through an optical telescope, observing the heavens in visible light. But beyond the visible, there is an entire invisible Universe out there to explore – and one way we can explore the unseen wonders of the cosmos is through radio astronomy. Here in West Virginia, we are lucky enough to have one of the premier radio astronomy facilities in the world, the Green Bank Observatory (GBO) in Pocahontas County, WV. The GBO is home to the Green Bank Telescope (GBT), the largest fully-steerable radio telescope in the world. The GBT is on the cutting edge of many modern astronomical discoveries, including topics ranging from dark matter to gravitational waves to mapping the surfaces of planets and moons to the search for life elsewhere.

Since we are so fortunate to have a wonder like the GBO in our very own backyard, it is important for us as West Virginians to educate our students about what this means to our state, and how it can help us learn things that are important to our futures. The aim of this lesson plan is to introduce students to physical science and engineering concepts by teaching them about the wonders of radio astronomy, and how to build their very own radio telescope in the form of a loop antenna. While the loop antenna is small and simple to build, it shares much in common with the GBT: it detects radio waves which tell us something about our Universe, it makes use of circuit components, it digitally processes and stores its data, and produces graphs which young astronomers can use to learn something new about the cosmos around them.

In this lesson plan, students will learn about radio astronomy, beginning with learning what a radio wave is, and sequentially learn about the electromagnetic spectrum, the history of radio astronomy, Earth's atmosphere and ionosphere, electricity and magnetism, how simple radios work, how circuits work, digital signal processing, basic programming, lifecycles of the stars, the Sun and solar activity, the aurora borealis, the Sun's effect on Earth, how to interpret data graphs, and how to write scientific reports and presentations. All of these concepts are learned in tandem with building the loop antenna project. The loop antenna is a very engaging project, with potential for exciting discovery: the antenna works by monitoring the signal strength of submarine communication radio signals over time, and large increases in the detected signal (marked by a large spike in the data graph) indicates that you have detected solar activity.

Over the course of this series of lessons, students will gain an awareness of various interesting fields of study ranging from engineering to computer science to astronomy, and even including history and art. Exposure to this variety of fields could spark inspiration for a future career or lifelong interest. The most important goal we have for this lesson plan is for students to find something that they're passionate about – something they care enough about to want to keep learning more. By giving students the chance to participate in a real research project with exciting, meaningful results, we hope to inspire in students that not only can they understand challenging concepts, but that they are capable of achieving their dreams and reaching for the stars.

Electromagnetic Spectrum Map Template (Lesson 2)



Electromagnetic Spectrum Map Image Key (Lesson 2)

1. AM/FM radio – radio waves
2. GPS – microwaves
3. TV remote control – infrared
4. Human eyesight – visible light
5. Radioactive element – X-rays
6. Gamma camera scan of the lungs – gamma rays
7. Sunscreen – blocks ultraviolet light
8. Radar system – radio
9. Blue topaz – gamma rays (*Note: gamma rays are used to turn white topaz into blue topaz)
10. Microwave oven – microwaves
11. Gamma knife surgery – gamma rays
12. Television reception – radio
13. Satellite communications – microwaves
14. Night vision goggles – infrared
15. Black light – ultraviolet
16. X-ray imaging – X-rays
17. Light bulb – visible light
18. Snakes' vision – infrared
19. Welding arc – ultraviolet
20. Lasers – visible light
21. Particles whirling around the Large Hadron Collider emit X-rays. (Maybe explain to students that the Large Hadron Collider speeds particles up to 99.99999% the speed of light and smashes them together to discover new particles)

Electromagnetic Spectrum Map – Multiwavelength Astronomy Activity Key (Lesson 3)

A. Green Bank Telescope – radio.
   Hints:
   1. I often look at really long wavelengths!
   2. I could pick up TV channels, but that's not my goal...
B. Jupiter – infrared.
   Hints:
   1. I'm warm, but not really hot like a star.
   2. You can see me in many different kinds of light, not just visible light.
C. Chandra space telescope – X-rays
   Hints:
   1. I have something in common with Superman.
   2. The things I see are very high-energy, but not the highest energy.
D. Centaurus A galaxy – gamma rays.
   Hints:
   1. I am emitting light at the highest-possible frequencies.
   2. The purple light in this image is very high-energy light, but the stars are from visible-light images.
E. Cosmic Background Radiation – microwaves.
   Hints:
   1. This light came from the time right after the Big Bang (when the Universe was formed).
   2. The cosmic background is pretty cold, but not the coldest of all.
F. The Hubble Space Telescope – visible light.
   Hints:
   1. I can see better in space because there are no clouds to block my vision.
   2. If your eyes were really big and you could go to outer space, you'd see what I see.
G. Karl G. Jansky Very Large Array – radio.
   Hints:
   1. All of my small dishes work together like one big telescope.
   2. Like the Green Bank Telescope, I like to check out low frequencies.
H. The Sun – ultraviolet.
   Hints:
   1. Although you see me every day, you don't see this invisible side of me.
   2. Your skin is affected by my emissions in this kind of light, which is why you wear sunscreen!
I. Neutral hydrogen (H1) gas in the Milky Way – microwave.

Hints:

1. H1 gas is cold, so the electromagnetic radiation it emits has low energy.
2. H1 gas is invisible — it is so cold that it doesn't emit visible light.

J. The Crab Pulsar – X-rays.

Hints:

1. My energy is high, so I am emitting light at very short wavelengths (but not the shortest!)
2. I am the result of a star exploding and then collapsing into a tiny spinning object.
3. I emit light in many parts of the electromagnetic spectrum – this image shows just one.

K. NASA Telescope Facility – infrared.

Hints:

1. I may look like an optical observatory, but I'm not...
2. If a snake had telescopic vision, it could see what I can see.

L. Galaxy Evolution Explorer (GALEX) Telescope (artist's impression) – ultraviolet.

Hints:

1. Though I am no longer operational, I could see in slightly higher frequencies than your eyes can.
2. My job was to study how galaxies change over time.

M. Fermi Bubbles – gamma rays.

Hints:

1. The Fermi Bubbles are the two big purple lobes in this image. The rest of the picture is taken in visible light.
2. The Fermi Bubbles emit light in the shortest-possible wavelength range.

N. The Hercules Star Cluster – visible light.

Hints:

1. I am made up of many old stars.
2. You can see me with a backyard telescope!

O. NASA's Compton space telescope – gamma rays.

Hints:

1. When I was operational, I could see the most high-frequency light of all.
2. The events I was able to see are rare because they require such high energies to occur.

P. Star forming region – infrared.

Hints:

1. The color of this image is a clue to the type of light it is (and it's not visible).
2. Star forming regions are hard to observe in visible light because dust clouds block out the light, but we can see them in other wavelengths!

Q. Supernova remnant – X-rays.

Hints:

1. I am a cloud of gas and dust left over after a star exploded.

2. This picture is made up of two layers. The stars appear in optical light, but the blue shape appears in a higher frequency kind of light (this is the kind you want to guess!)

R. Pulsar data – radio.

   Hints:

   1. The Green Bank Telescope studies pulsars.
   2. Pulsars emit light in many parts of the electromagnetic spectrum, as we've seen earlier, but they are strongest at low frequencies.

S. The Sombrero Galaxy – visible light.

   Hints:

   1. I shine from the light of the many stars that form my galactic disk.
   2. The dark stripe running through me is made of opaque gas and dust that my light can't get through.

T. James Clerk Maxwell Telescope (JMCT) – microwave.

   Hints:

   1. The JMCT could figure out if you were heating up a Hot Pocket.
   2. This telescope looks at light that isn't the lowest frequency, but close.

Lab Report

Name: ______________________

Date: _______________________

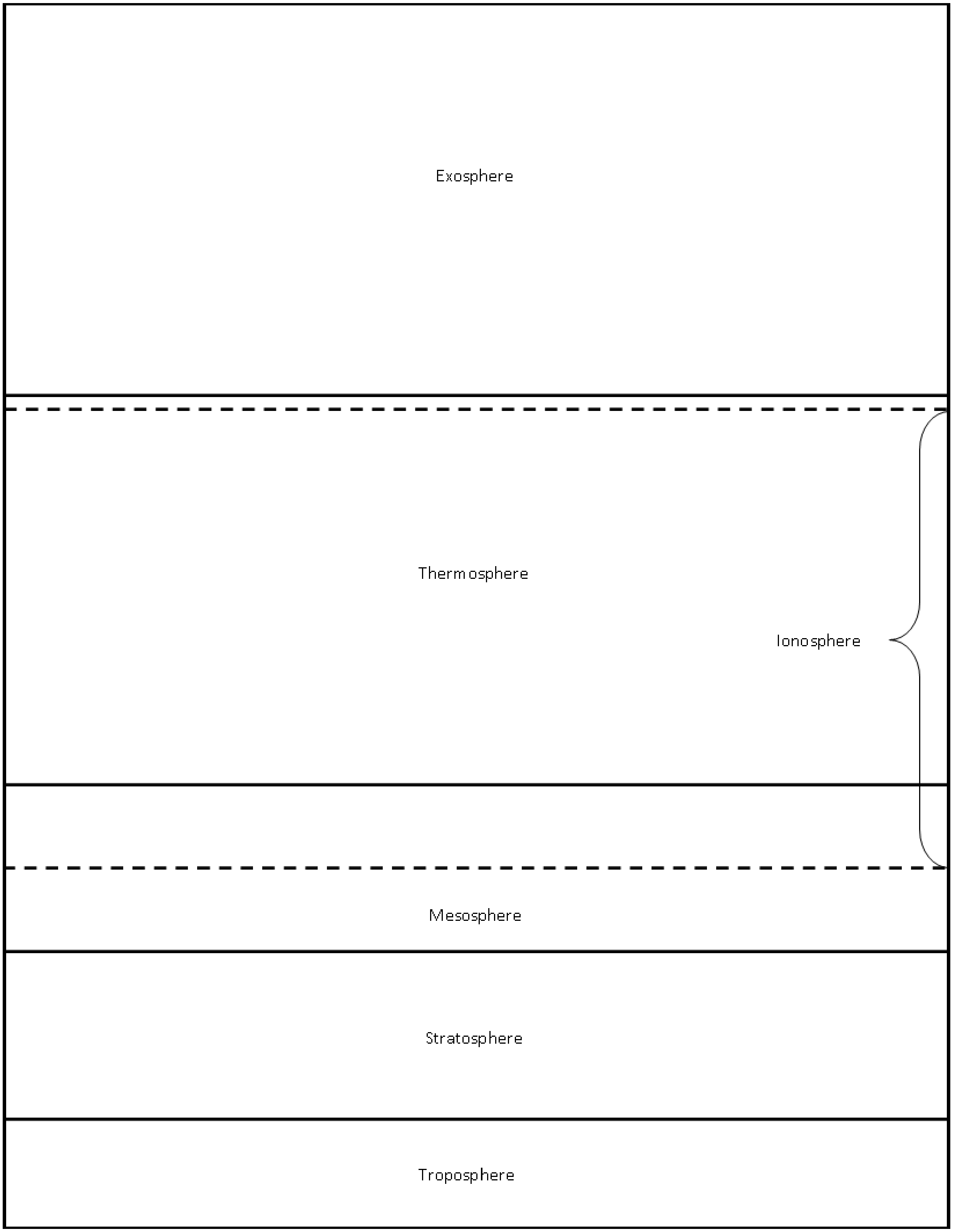
Hypothesis:

Methods:

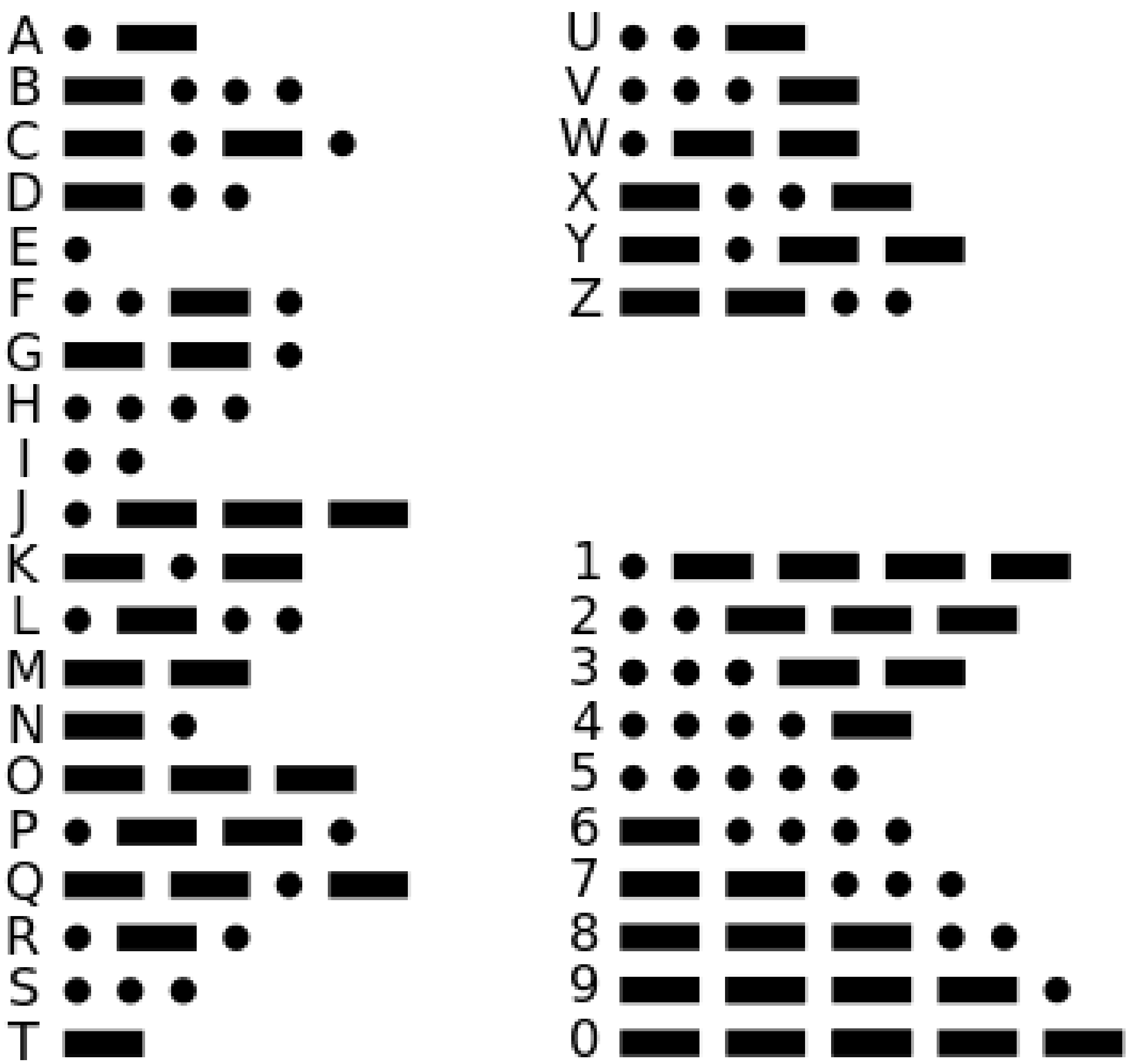
Results:

Conclusions:

Atmospheric Layers Diagram Template (Lesson 5)



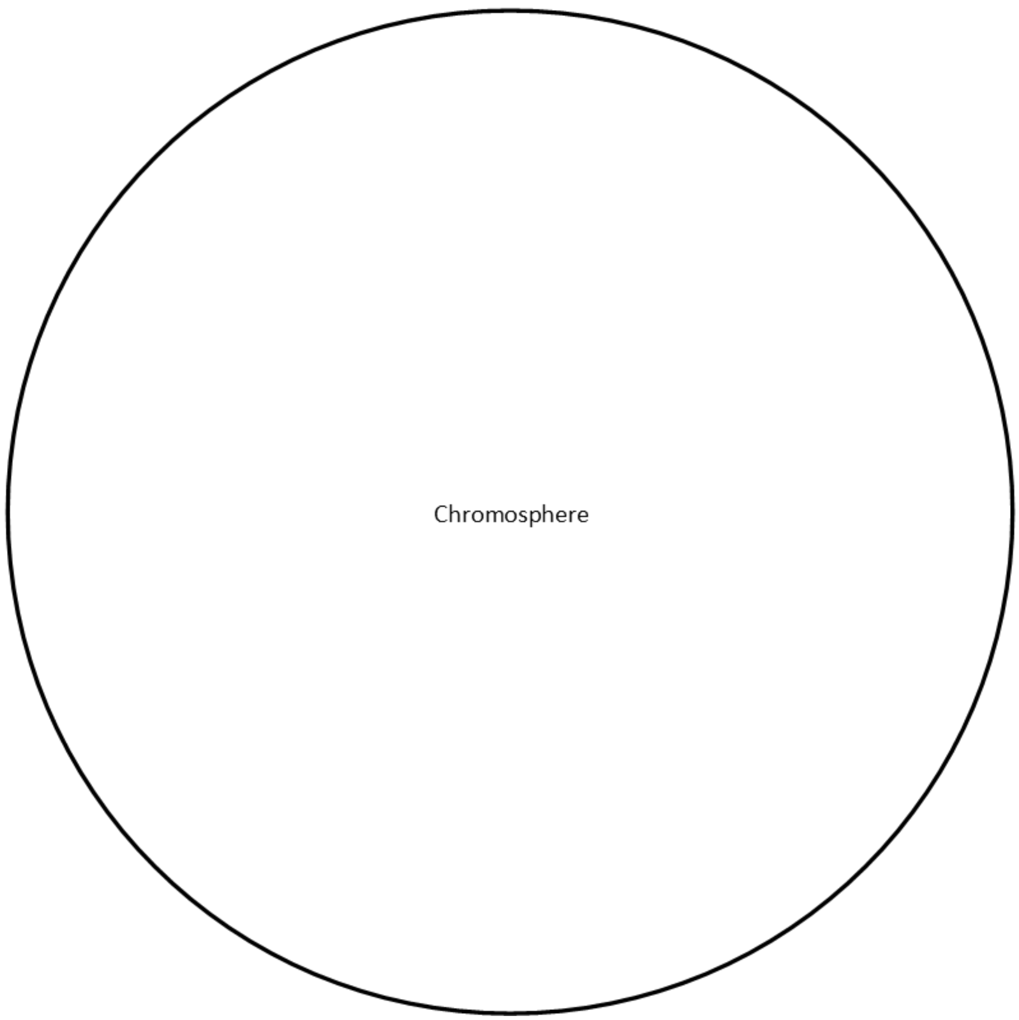
Morse Code Key (Lesson 7)

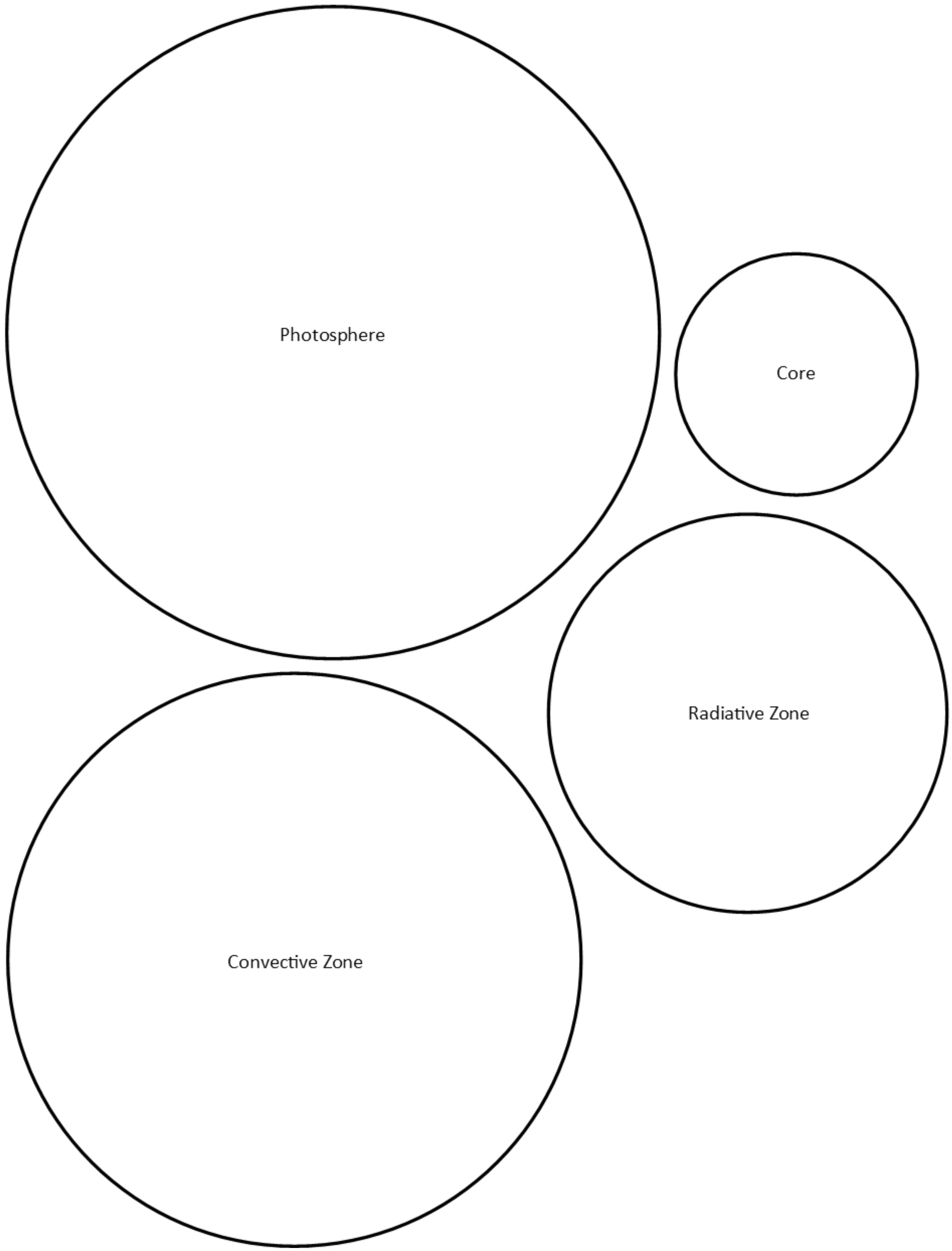


Key courtesy: commons.wikimedia.org/wiki/File:International_Morse_Code.svg

How to Make a Sun Diagram

1. Trace the templates labelled “Core”, “Radiative Zone”, “Convective Zone”, “Photosphere”, and “Chromosphere” on different-colored sheets of construction paper (preferably in warm colors), then cut them out.
2. Tear out rough-edged circle that is larger than the “Chromosphere” circle from another sheet of construction paper. This will be your “Corona”.
3. Using a solid sheet of construction paper as a base, glue or tape each of your solar layers on top of each other, starting with the “Corona”, then the “Chromosphere”, and so on. Once you have completed this step, label each layer on your diagram with a marker or colored pencil. Then, write a title (“Layers of the Sun”) across the top of your page to complete your diagram.




Photosphere
Core
Radiative Zone
Convective Zone

Loop Antenna Data Collection Sheet

Name ____________________________

Date: ____________________________

Antenna Commissioning Checklist:

- ☐ Attach antenna to circuit board following procedure in the Instruction Manual
- ☐ Connect circuit board to upconverter with a cable
- ☐ Connect upconverter to a power supply (your computer, or a cell phone charger) with a USB cord
- ☐ Connect upconverter to the SDR dongle using the small connector cable
- ☐ Plug the SDR dongle in to your computer's USB port
- ☐ Flip the switch on the upconverter to "Upconvert" (not "Passthrough")
- ☐ Run the GNU Radio Companion software
- ☐ Open the Loop Antenna flowgraph file
- ☐ Change the name of the file in the "File Source" as instructed in the manual
- ☐ Click the "Start" button to begin your observations

Observation start time and date: __________________________________

Observation stop time and date: __________________________________

After completing your observations, do you notice any interesting features? If so, record them in this table (note that classifications of features could include interference, a storm, sunrise or sunset signatures, or solar activity):

Date of feature	Time	Classification	Other notes

Date of feature	Time	Classification	Other notes

Research Question Sheet #1

The topic of your group's scientific paper and presentation will be ***The Sun's Effect on Earth***. Focus your research and presentation of your results around the following questions:

- How do solar flares impact the Earth and its systems?
- Can scientists predict solar flares at all, and if so, how?
- What do scientists know about how solar flares are formed now?
- Did you detect solar flares with your loop antenna?
- What could your results do to help scientists understand how solar flares work?

Research Question Sheet #2

The topic of your group's scientific paper and presentation will be ***The Evolution of the Sun***. Focus your research and presentation of your results around the following questions:

- Do other stars develop flares on their surfaces?
- Do scientists think the Sun is more or less active now than it used to be, or about the same? Or are they not sure?
- Do scientists think that stars' flare behavior changes as they age?
- How might the Sun's behavior change as it gets older?
- What do your observational results tell us about the Sun's stage in its life?

Research Question Sheet #3

The topic of your group's scientific paper and presentation will be ***Engineering a Radio Telescope***. Focus your research and presentation of your results around the following questions:

- What are some factors that need to be accounted for when building a radio telescope? Some factors could include frequency range and the strength of the signal you're trying to detect.

- How is your loop antenna like a big radio telescope such as the Green Bank Telescope? How is it different?

- Can you think of any ways to improve the loop antenna's design?

Research Question Sheet #4

The topic of your group's scientific paper and presentation will be ***The Sun's Impact on Our Civilization***. Focus your paper and presentation around the following questions, while making sure to incorporate how your observations relate to this central topic:

- What are some ways that the Sun affected the culture of ancient civilizations?
- What are some myths that ancient people told to explain things like aurorae and solar eclipses?
- Did people long ago build prehistoric observatories or spiritual sites with astronomical significance? Try searching the term "astroarchaeology".
- How does the Sun affect our culture now?
- How are our loop antenna observations similar to the ancient peoples' observations of the Sun? In general, how is the modern-day science of astronomy related to the astronomical observations of prehistoric people?

Research Question Sheet #5

The topic of your group's scientific paper and presentation will be ***How Interference Affects Astronomy***. Focus your paper and presentation around the following questions, while making sure to incorporate how your observations relate to this central topic:

- Did you notice any spiky patterns in your data that might be caused by interference?
- How did this interference impact your ability to identify other features in your data (like sunrise/sunset signatures or solar activity, if you detected any)?
- Do you notice more interference at certain times of the day or night? What could this mean?
- How might interference affect observations with a telescope like the Green Bank Telescope?
- What can astronomers and engineers do to reduce the negative impact of interference? What are some things they've already done to address this problem?

STEM Opportunities in West Virginia

- Radio Astronomer for a Day is an overnight field trip activity at the Green Bank Observatory (GBO). Students participating in Radio Astronomer for a Day get the opportunity to explore the observatory and learn to operate a 40-foot radio telescope! More info: https://greenbankobservatory.org/education/student_research/

- Skynet Junior Scholars is an educational program that allows students to remotely operate optical telescopes from around the world and the Green Bank 20-Meter radio telescope. More info: https://skynetjuniorscholars.org/

- Physicists Inspiring the Next Generation (PING) – this program is geared toward female and underrepresented minority students who are interested in pursuing a career in STEM. The program consists of a 2-week science camp at the GBO. More info: https://greenbankobservatory.org/education/student_research/ping/

- The Pulsar Search Collaboratory is a program for students age 13+. In this program, students get to search through real science data with the chance to discover a pulsar! More info: http://pulsarsearchcollaboratory.com/