STEM

Science • Technology • Engineering • Math

Unit Leader's Guide

STEM in a BOX
Cub Scout
NOVA Award Program

Michigan Crossroads Council, BSA
STEM Programs
137 S. Marketplace Blvd
Lansing, MI 48917
(316) 664-9112
www.michiganscouting.org/STEM

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STEM Program Guide

Introduction

The Boy Scouts of America launched the Nova awards program in an effort to incorporate learning about Science, Technology, Engineering and Math (STEM). The national BSA website details the goals and aims of the program and a link is provided at the end of the document.

The program is open to Cub Scouts, Boy Scouts and Venturing and the activities and requirements are age appropriate and designed to stimulate interest in STEM.

Why STEM

In today's world, the ability to understand the concepts around STEM has proven essential to developing strong career paths. The Boy Scouts of America is in the business of developing youth and STEM provides a supplement to the traditional Scouting program and complements the outdoor activities and a Scout's journey to Eagle.

Secondly, many aspects of our lives involve STEM whether we know it or not. From simple calculations about how early we should leave for an appointment to calculating the amount of paint we need to buy to cover a child's bedroom are all STEM-related activities. By bringing STEM activities into the Scouting program we can enhance the Scouting experience and cultivate the natural curiosity of youth.

Finally, various Scout Activities from building a Pinewood Derby car to archery to cooking to fire building involves a STEM concept. STEM is literally all around us and we make use of it every day. What better way to complement the traditional Scouting program than to add an element that explains the physics behind archery in addition to teaching the skill.

What Is a STEM Award

There are two types of STEM awards: Nova and Supernova awards. The Nova awards incorporate various STEM-related activities, e.g., reading, viewing, experimenting, and outings along with earning STEM related adventure loops, pins or merit badges. The Supernova awards are more rigorous and build upon the Nova awards.

Nova Awards

To earn a Nova award a Cub Scout, Boy Scout or Venturer can earn traditional belt loop/pin or merit badge in conjunction with satisfying other specific requirements for the individual Nova award.

Nova awards are guided by a Nova awards counselor. The counselors need to have an interest in helping with the STEM program and a general familiarity with STEM, but in no way needs to be a scientist, technologist, engineer or mathematician. A counselor is any registered adult age 21 or older (unless he/she is working with his/her own child).

The STEM initiative is meant to be "fun" and cultivate a desire to explore additional STEM concepts and ideas much like the traditional Scouting program asks youth to seek a broader outdoor experience.

Nova awards are work done at a unit level and the barrier to entry for each unit is low. A willingness to try is all that is required of the adult leader to help a Scout move forward with an award.

Since STEM stands for science, technology, engineering and mathematics, there is a Nova award for each category at each level of Scouting. They are listed as follows:

CUB SCOUT NOVA

- 1-2-3 Go! Tracking Form
- Science Everywhere Tracking Form
- Swing! Tracking Form
- Tech Talk – Tracking Form

BOY SCOUT NOVA

- Designed to Crunch Tracking Form
- Shoot! Tracking Form
- Start Your Engines Tracking Form
- Whoosh! Tracking Form

VENTURING NOVA

- Hang On! Tracking Form
- Launch! Tracking Form
- Numbers Don't Lie Tracking Form
- Power Up Tracking Form

Supernova Awards

These awards are a higher level award requiring more rigor to complete. They are built, however, on the foundation of the Nova awards. Thus the youth would complete a number of Nova awards as pre-work to beginning the Supernova project.

Supernova awards mentors must be 21 or older, be subject matter experts in a STEM (science, technology, engineering, mathematics) field and be a registered and approved member of Michigan Crossroads Council.

For the Supernova awards, the youth will work with a Supernova mentor who is a registered member and approved by the Michigan Crossroad Council's Advancement Committee.

Keys to a Successful STEM Program

The STEM program complements the traditional Scout program and provides another avenue for exploration, leadership development and fun. For many youth, the allure of science and technology is overwhelming and used properly the STEM program can be a powerful recruiting tool.

First, make it fun. The STEM program is not designed to supplement traditional schooling, but rather to spark the imagination and natural curiosity of youth.

Second, incorporate it into your traditional program. It is simple to add a STEM element to Scouting activities which complements the "what" of the activity with the "how and why" it works. For example, the Pinewood Derby event at the Cub Scout level is all about science and engineering.

Start with a group session to introduce the topic to your pack, troop or crew. The project should have a physical element.

Most important is to review the information in websites of both the BSA and the Michigan Crossroads Council. Everything a unit needs to start a STEM initiative is located on the website including the Nova awards guidebooks or you can purchase the guidebooks at your local Scout shop.

Please note: Nova Award Books for Cub Scouts are available, as of June 2015, for the NEW Cub Scout Program. Check the printing date on your books and ONLY use the June 2015 books if you are starting your Nova Awards after 6/1/2015. Your local Scout Shop will have only these books on hand now.

How to Start

Up until now, we've talked about what the program is about. Now, we discuss how to practically launch the program in your unit. The following is a practical step-by-step guide to getting the program up and running.

Step 1: Contact your District STEM Chair and include STEM in your program planning.

This individual is charged by his/her district with helping to roll the STEM program out to each unit. They will be active at roundtable around STEM topics and will be willing to discuss with your unit leadership about the STEM program.

The District STEM Chair can make a presentation to your unit leadership and/or unit membership. Leverage this resource.

Part of the discussion will center on how to incorporate STEM into your program planning and recruiting efforts.

Step 2: Recruit Nova awards counselors.

The Nova awards counselor is a unit appointed position, and can be any registered adult age 21 or older (unless he/she is working with his/her own child). To be effective the single most important aspect for the counselor is a willingness to help. While an interest in and a familiarity with STEM concepts is helpful, it is not in the least bit required. In fact, any adult leader can administer the Nova awards program.

The above notwithstanding, each and every unit probably has a number of individuals who have STEM careers and would be more than willing to be subject matter experts (SME's) for your unit. Use the resource survey (see Resources section) to identify the candidates.

Additional resources can be found at roundtable and on the Michigan Crossroads Council website.

Step 3: Schedule a group STEM activity.

In your unit, designate a pack meeting, troop meeting or crew meeting to launch and explain the STEM program to the youth. This is not just a lecture, but a practical and hands on approach where you will get started on a Nova award as a group.

Select a single Nova award for your unit and work with your District STEM Chair to help launch. Have a Nova awards counselor introduce the award at a group meeting and be available to guide participants through the award. Start by doing part of the award during a unit function. The activities should include a practical exercise—watching a video or conducting individual experiments.

Sample activities include:

- Show a video that applies to an award.
- Do a STEM-related demonstration.
- Go on a STEM-related field trip.

Examples can be found at: http://mindtrekkers.mtu.edu

Step 4: Call for Supernova awards mentors (optional).

This step is needed if a member in your unit wants to pursue the Supernova award. The Supernova awards mentor is similar to a merit badge counselor, in that they must be a registered leader and have domain expertise. In simple terms, they must have STEM credentials. They will need to fill out an application and be approved by the Michigan Crossroad Council's Advancement Committee as a Supernova mentor.

Resources

The following are links to assets and websites that can aid in your STEM journey:

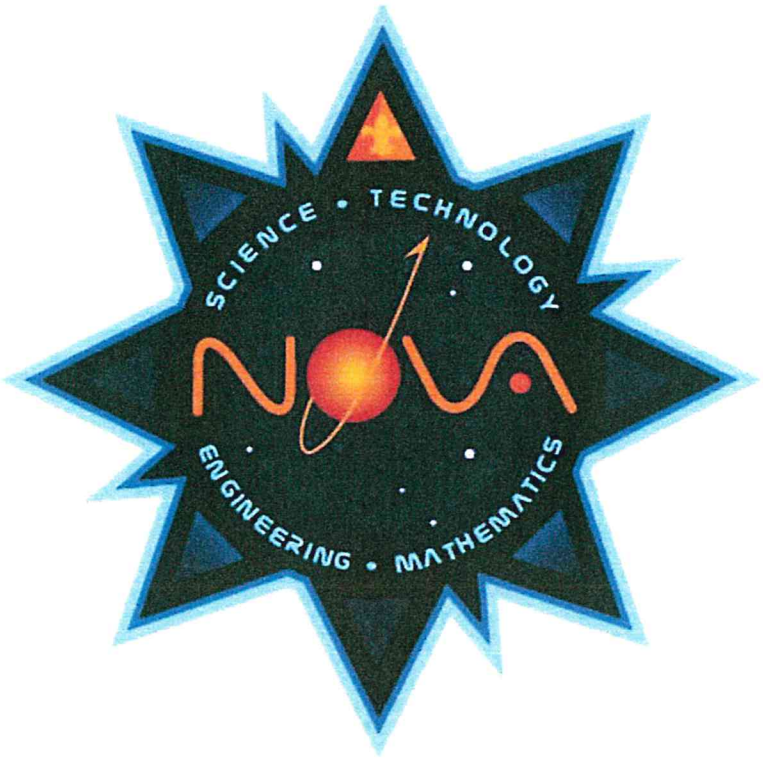
The national BSA website (http://www.scouting.org/stem/Awards/AboutNova.aspx) begins detailing the goals and aims of the program.

Check out the Michigan Crossroads Council calendar, and search on STEM to find events, activities, camps, and Nova Award specific events in our Council: http://www.michiganscouting.org/Calendar

CUB SCOUT NOVA

STEM in a Box

1-2-3 GO Kit

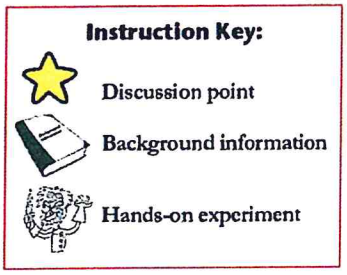


BOY SCOUTS OF AMERICA®
MICHIGAN CROSSROADS COUNCIL

How to use this guide

The Stem-on-the-Go program is designed to give Scout Leaders an easy, user-friendly way to present concepts to their Scouts. Each module contains everything you need to complete the requirements for that subject. Whenever possible, we've provided you with background information to help with the idea. Experiments were designed to make the learning fun and interactive for the Scouts.

This instruction key gives you visuals to help you know what each lesson entails: For example, when you see a yellow star, you know that this information will be a discussion point you can use with your Scouts to explore a topic.



Be sure to look through the Stem-on-the-Go box before you use it for the first time. There may be some information that will be helpful to read before you have a room full of rambunctious boys ready to do some science!

Please be sure to mark any supplies that need to be replenished before you pass the box on to the next Leader.

Most importantly, have fun with your Scouts! You are doing important work, inspiring and engaging future engineers, doctors, chemists, rocket scientists, electricians and more. Thank you for supporting the Scouts program.

Stem-on-the-Go

1,2,3 Go!

Introduction

The 1,2,3 Go! module is designed to help Cub Scouts explore how math affects their life each day. Math and physics are used in almost every kind of invention, including cars, airplanes, and telescopes. Math also includes cryptography, the use of secret codes.

The materials in this box provide the resources to complete the award.

- Award Tracking Forms
- Cub Scout Nova Awards Guidebook

Directions

Review the 1,2,3 Go! requirements (Page 29-32) and the counselor instruction (Page 70) in the Cub Scout Nova Awards Guidebook. The following notes instruct how to use the materials provided with this box.

Requirement (1.A)

Watch an episode or episodes (about one hour total) of a show that involves math or physics. Then do the following:

1. *Make a list of at least two questions or ideas from what you have watched.*
2. *Discuss two of the questions or ideas with your counselor.*

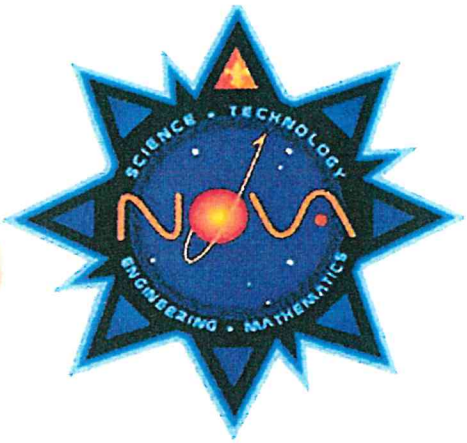
Suggested videos:

National Geographic for Kids
http://video.nationalgeographic.com/video/kids/

Mythbusters clips and short episodes
http://www.discovery.com/tv-shows/mythbusters

HOW MUCH DO I WEIGH ON OTHER PLANETS?

Space Science & Technology



Requirement (3.A.1-3)

Choose TWO options from A or B or C and complete ALL the requirements for those options. Keep your work to share with your counselor. The necessary information to make your calculations can be found in a book or on the Internet. (See the Helpful Links box in the NOVA Guidebook, page 33 for ideas.) You may work with a parent or your counselor on these calculations.

A. Choose TWO of the following places and calculate how much you would weigh there.

1. *On the sun or the moon*
2. *On Jupiter or Pluto*
3. *On a planet that you choose*

How Much Do I Weigh on Other Planets?

Refer to the background info provided to learn about the difference between weight and mass.

Learning Concept

Gravity is a universal, natural force that attracts objects to each other. Gravity is the pull toward the center of an object; let's say, of a planet or a moon. When you weigh yourself, you are measuring the amount of gravitational attraction exerted on you by Earth. The Moon has a weaker gravitational attraction than Earth. In fact, the Moon's gravity is only 1/6 of Earth's gravity. So, you would weigh less on the Moon.

Work with Scouts to fill out the "How Much Do I Weigh on Other Planets?" worksheet. You will need pencils and calculators. Alternatively, you may send this home with Scouts to complete on their own.

How Much Do I Weigh On Other Planets?

You've probably seen video footage of astronauts walking on the moon. They seem to float between each step. Remember that the moon has about 1/6 the amount of gravity that the Earth has? Well, if you went to the moon, you'd weigh less than you do here on Earth. Does this mean you would suddenly be thinner on the moon? Absolutely not. Your mass would be the same -- there is no less of you on the moon. But your weight is different because the moon's gravity is different.

1. Weigh yourself, or guess what you weigh.
2. Record your mass in the chart below. Your mass is your weight on Earth.
3. Multiply your mass times the gravity in each row to figure out your weight at each location. Show the equation you used to calculate your new weight. *
4. Where do you weigh the most? Where do you weigh the least?

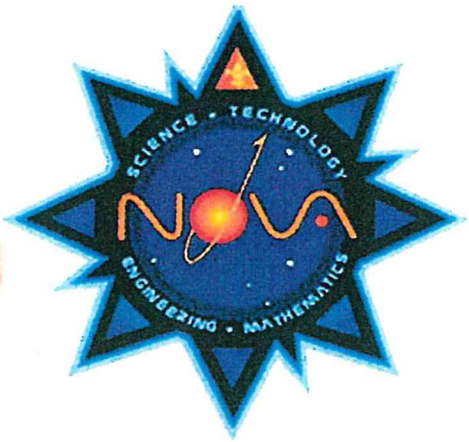
Location	Mass	Gravity	Equation	Weight
Earth		1		
Outer space		0		
Earth's moon		0.17		
Venus		0.90		
Mars		0.38		
Mercury		0.38		
Jupiter		2.36		
Saturn		0.92		
Uranus		0.89		
Neptune		1.13		
Pluto*		.07		

To calculate your weight: **mass x gravity = weight**

***If you would like to convert your weight from pounds to kilograms, multiply your weight by 0.45.**

CODES AND CIPHERS

Space Science & Technology



Requirement (4.) Secret Codes

A. Look up, then discuss with your counselor each of the following:

1. *Cryptography*
2. *At least three ways secret codes or ciphers are made*
3. *How secret codes and ciphers relate to mathematics*

What is Cryptography?

Cryptography is the science of information security. The word is derived from the Greek *kryptos*, meaning hidden. Cryptography is closely related to the disciplines of cryptology and cryptanalysis. Cryptography includes techniques such as microdots, merging words with images, and other ways to hide information in storage or transit. However, in today's computer-centric world, cryptography is most often associated with scrambling plaintext (ordinary text, sometimes referred to as cleartext) into ciphertext (a process called *encryption*), then back again (known as *decryption*). Individuals who practice this field are known as *cryptographers.*

See enclosed pages, "Types of Ciphers" laminated examples to help facilitate discussion about how codes and ciphers are made.

B. Design a secret code or cipher. Then do the following:

1. *Write a message in your code or cipher.*
2. *Share your code or cipher with your counselor.*

Designing Your Own Cipher

See the following material, "How to Create a Number Shift Cipher". Then, show students the Caesar Cipher and have them each construct their own Cipher Wheel to take home.

STEM-in-a-Box Experiment

Investigating Codes and Ciphers

Codes and Ciphers

Cryptography is split into two ways of changing the message systematically to confuse anyone who intercepts it: these are codes and ciphers. Many people believe, and use, the word code to mean the same thing as cipher, but technically they are different.

A code is a way of changing the message by replacing each word with another word that has a different meaning. For example, "Burn the City" could become "Take the rubbish" where the word "burn" is represented by the codeword "take", and similarly for "city" and "rubbish". Using codes requires a codebook, which contains all such codewords. Considering the large number of words in most languages, this is normally quite a large book, making the use of codes rather cumbersome (it is a bit like a French dictionary, giving the translation to and from the codeword).

However, they can be used to encode key words in a message. Consider the message "Kill him as soon as possible". With a simple change of a single word this becomes "Meet him as soon as possible", which may pass through security detection without being noticed. So, although potentially hard to use, a simple code can be very effective, since even if the message is intercepted, they can be used so that the code reads as an innocent or unrelated topic.

Ciphers, on the other hand, convert the message by a rule, known only to the sender and recipient, which changes each individual letter (or sometimes groups of letters). Ciphers, are significantly easier to use than codes, since the users only have to remember a specific algorithm (a mathematical word for process) to encrypt the message, and not a whole dictionary of codewords. The major setback for ciphers compared to codes is that if someone finds a message that has been encrypted using a cipher, the output is almost certainly going to be a random string of letters or symbols, and as such the interceptor

will know straight away that someone wanted to hide this message.

The task of the cryptographer is to create a system that is easy to use, both in encryption and decryption, but remains secure against attempts to break it. For this reason, many ciphers have developed over the last 4,000 years to try to stop people from discovering what it is that their secret message says.

Conventions in Cryptography

Throughout the site various cryptographic conventions will be used, which are explained here.

The plaintext is the message that is being encrypted by the sender of the message, and will be written in lowercase letters, and surrounded by quotation marks.
The ciphertext is the encrypted message that is actually sent to the recipient to be decrypted, and will be written using uppercase letters, and surrounded by quotation marks.

An intercept is a piece of encrypted text that has been discovered by an interceptor. That is, it is a ciphertext when you do not know the cipher used.
Most ciphers use a key to make the encryption unique and hence more secure. The key usually takes the form of either a number or a word, and it always changes the more general algorithm for the encryption in some way. By using a key, the sender is trying to make the plaintext irretrievable should the ciphertext fall into the hands of an interceptor who does not know the key, even if they know which cipher has been used. This is at the very heart of cryptography, and is known as Kerckhoffs's Principle (or Shannon's Maxim). The key will always be written in lowercase, and in italics.

The alphabet used in the encryption process can make a big difference to the ciphertext. It consists of the letters and symbols which will be transformed by the cipher. More importantly, any symbol which is NOT in the alphabet will be left unaltered in the ciphertext. The standard alphabet we shall use is the 26 Roman Letters "abcdefghijklmnopqrstuvwxyz". This means that any spaces, punctuation marks or numbers will not be changed in the ciphertext. Other alphabets can also be used containing these extra characters, and examples will be given for the more simple ciphers using these.

Type of Ciper: Monoalphabetic Substitution Ciphers

Substitution ciphers are probably the most common form of cipher. They work by replacing each letter of the plaintext (and sometimes punctuation marks and spaces) with another letter (or possibly even a random symbol).

A monoalphabetic substitution cipher, also known as a simple substitution cipher, relies on a fixed replacement structure. That is, the substitution is fixed for each letter of the alphabet. Thus, if "a" is encrypted to "R", then every time we see the letter "a" in the plaintext, we replace it with the letter "R" in the ciphertext.
A simple example is where each letter is encrypted as the next letter in the alphabet: "a simple message" becomes "B TJNQMF NFTTBHF". In general, when performing a simple substitution manually, it is easiest to generate the ciphertext alphabet first, and encrypt by comparing this to the plaintext alphabet. The table below shows how one might choose to, and we will, lay them out for this example.

Plaintext Alphabet	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t
Ciphertext Alphabet	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U

The ciphertext alphabet for the cipher where you replace each letter by the next letter in the alphabet

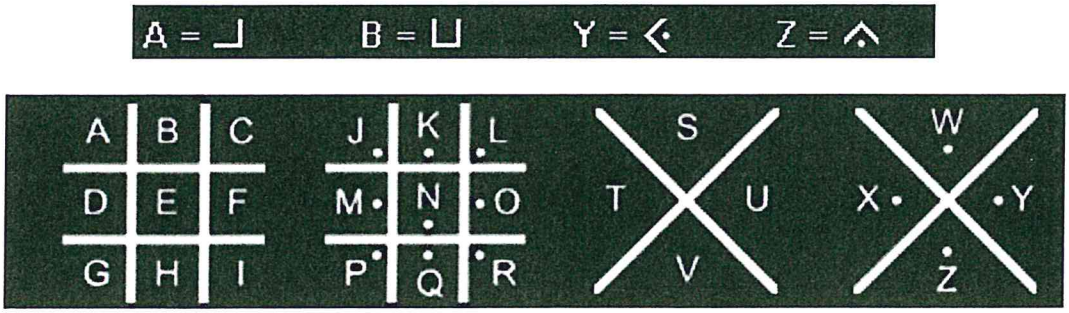
There are many different monoalphabetic substitution ciphers, in fact infinitely many, as each letter can be encrypted to any symbol, not just another letter.
The history of simple substitution ciphers can be traced back to the very earliest civilizations, and for a long time they were more than adequate for the purposes for which they were needed. By today's standards they are very weak, and incredibly easy to break, but they were a very important step in developing cryptography.

Type of Ciper: Pigpen Cipher

The Pigpen Cipher is another example of a substitution cipher, but rather than replacing each letter with another letter, the letters are replaced by symbols. The cipher has an interesting history: although its true origins are unknown, it has been used by many groups. Most notoriously, it was the cipher of choice for use by the Freemasons, a secret society in the 18th Century. In fact, they used it so much, that it is often referred to as the Freemasons Cipher. However, it was not exclusively used by them, with Union prisoners in Confederate camps using it to communicate in the American Civil War.

Encryption
The encryption process is fairly straightforward, replacing each occurrence of a letter with the designated symbol. The symbols are assigned to the letters using the key shown below, where the letter shown is replaced by the part of the image in which it is located.

For example:

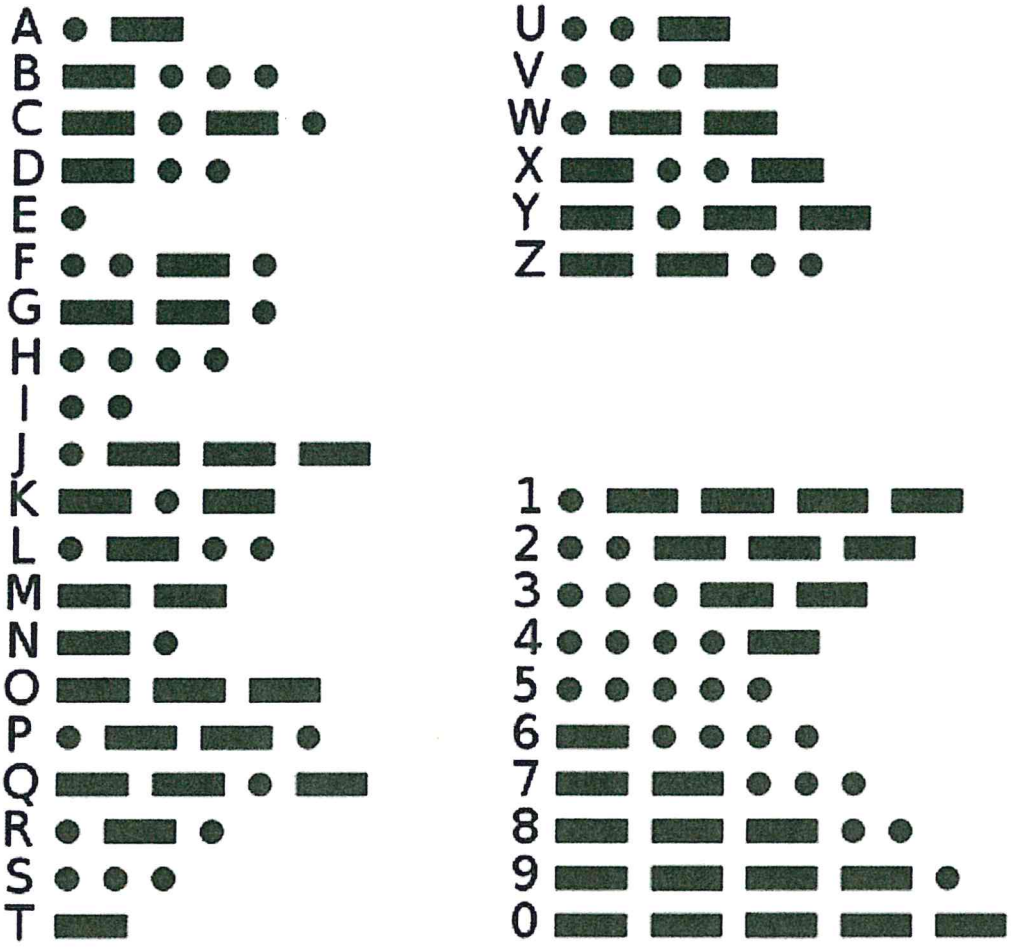


Type of Ciper: Morse Code

One of the most famous examples of a cipher in regular use is Morse Code (which is not a code, but rather a cipher). Morse Code has the benefit that it can be transmitted in several ways, such as written, by sound or by light. Each letter is replaced by a series of dots and dashes as given by the key below.

International Morse Code

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to seven dots.



The International Version of Morse Code is accepted as the standard. There are rules for how messages should be transmitted to avoid confusion.

The brilliance of the Morse Code system is that it can also be transmitted as an audio signal, and was originally used to send messages via telegraph (before telephones

had been invented). In this form, each dot is given by a short beep, and a dash by a longer beep (three times the length of a dot). There are various other rules as shown in the key above regarding the length of gaps and other things in transmission. Morse code has played a pivotal role in the development of technology, specifically telecommunication. Although not secure, since the key is widely known, it is still an interesting use of ciphers in the world today (many boats and planes still use Morse Code to communicate in bad weather when voices sounds crackly), and most importantly, the development of the Code went hand in hand with other technological discoveries (a story which we shall see repeats often in the history of Cryptography).

Try out your Caesar Cipher

Use your Caesar Cipher to encode the following messages:

1. Caesar cipher with shift +3
   hello tom

2. Caesar cipher with shift +12
   klondike nuggets

Decode the following messages:

3. Caesar cipher with shift +5
   ltytufwnx

4. Caesar cipher with shift +21 = −5
   adiyevhznwjiy

ANSWER KEY

Encode the following messages.

1. Caesar cipher with shift +3
   hello tom
   khoorwrp

2. Caesar cipher with shift +12
   klondike nuggets
   wxazpuwqzgssqfe

Decode the following messages.

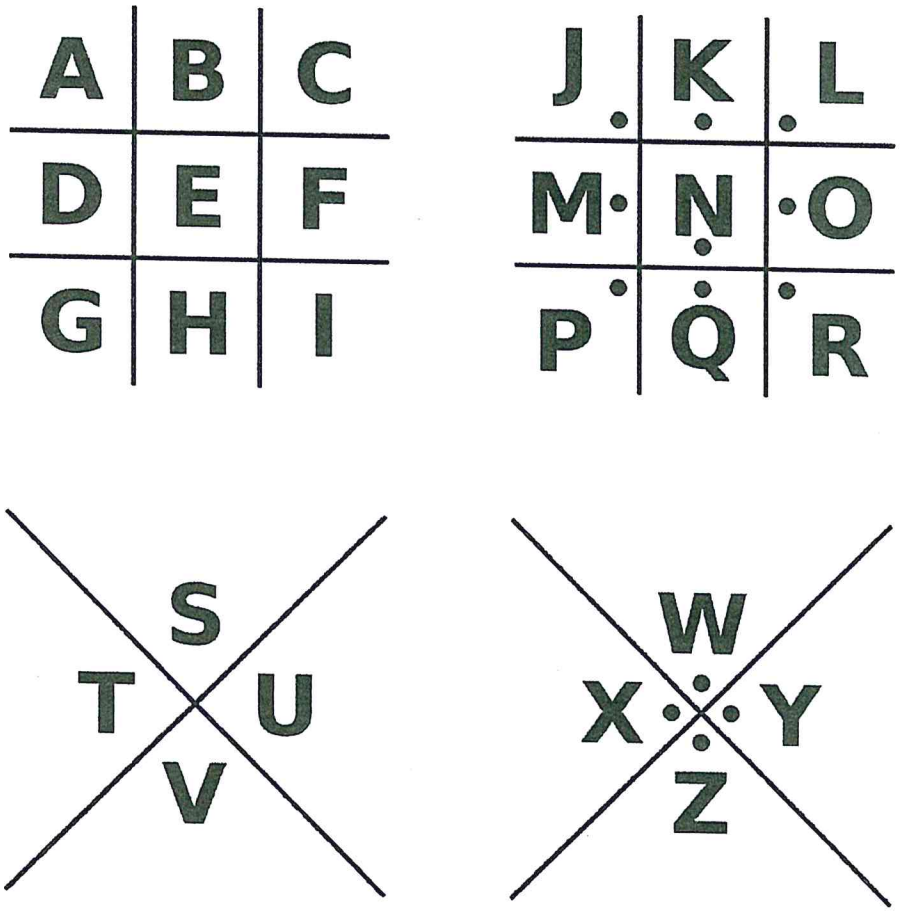
3. Caesar cipher with shift +5
   ltytufwnx
   go to Paris

4. Caesar cipher with shift +21 = −5
   adiyevhznwjiy
   find James Bond

Monoalphabetic Substitution Cipher

Plaintext Alphabet	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
Ciphertext Alphabet	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Pigpen Cipher



International Morse Code

A ●−	J ●−−−	S ●●●
B −●●●	K −●−	T −
C −●−●	L ●−●●	U ●●−
D −●●	M −−	V ●●●−
E ●	N −●	W ●−−
F ●●−●	O −−−	X −●●−
G −−●	P ●−−●	Y −●−−
H ●●●●	Q −−●−	Z −−●●
I ●●	R ●−●	

STEM-in-a-Box Experiment

How to Make A Number Shift Cipher

	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I/J	K
3	L	M	N	O	P
4	Q	R	S	T	U
5	V	W	X	Y	Z

Encrypting a Number Shift Cipher (You will need the Polybius Grid)

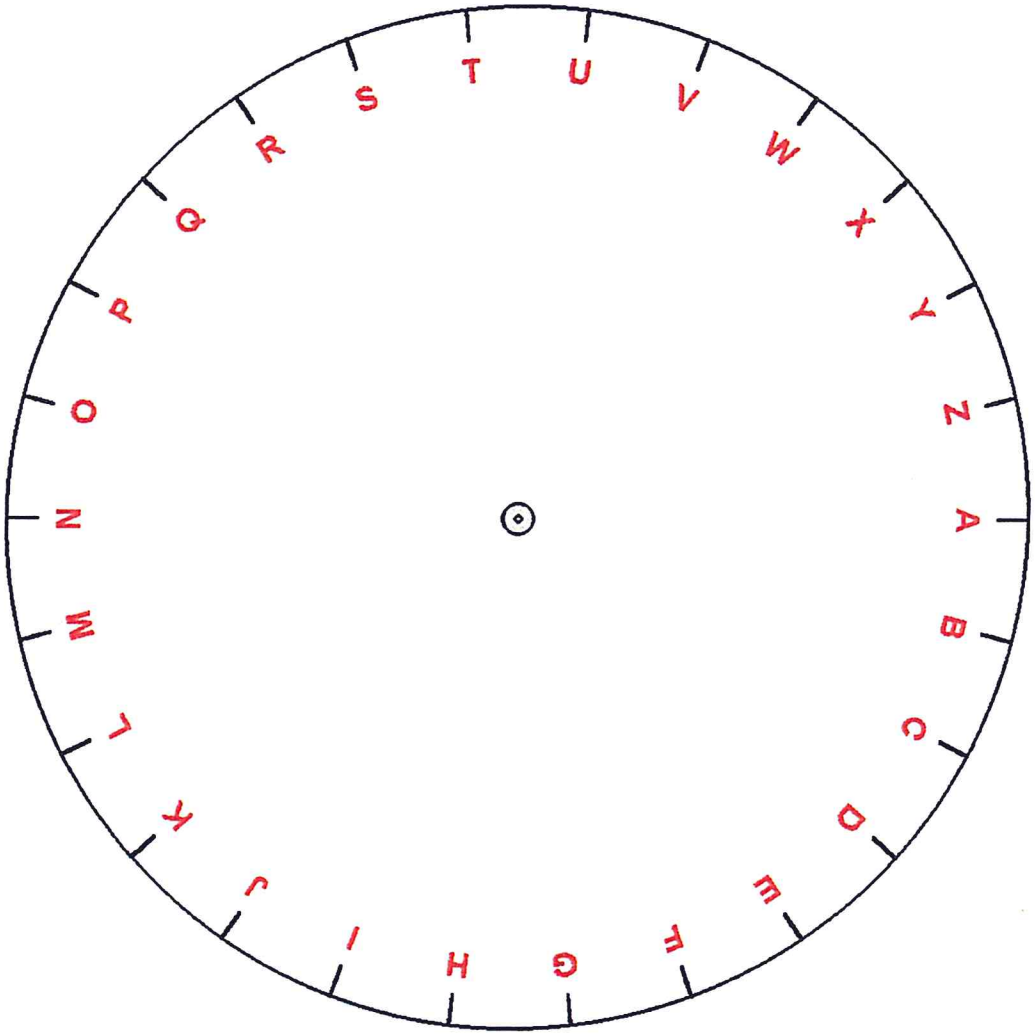
1. Write down your **plaintext** message on a piece of paper.
2. Begin encrypting your message by locating the first letter of your plaintext message in the grid.
3. Write down the row number followed by the column number.
4. Continue until your entire message has been encrypted.
5. To make your message more secure, leave out the spaces between each word.

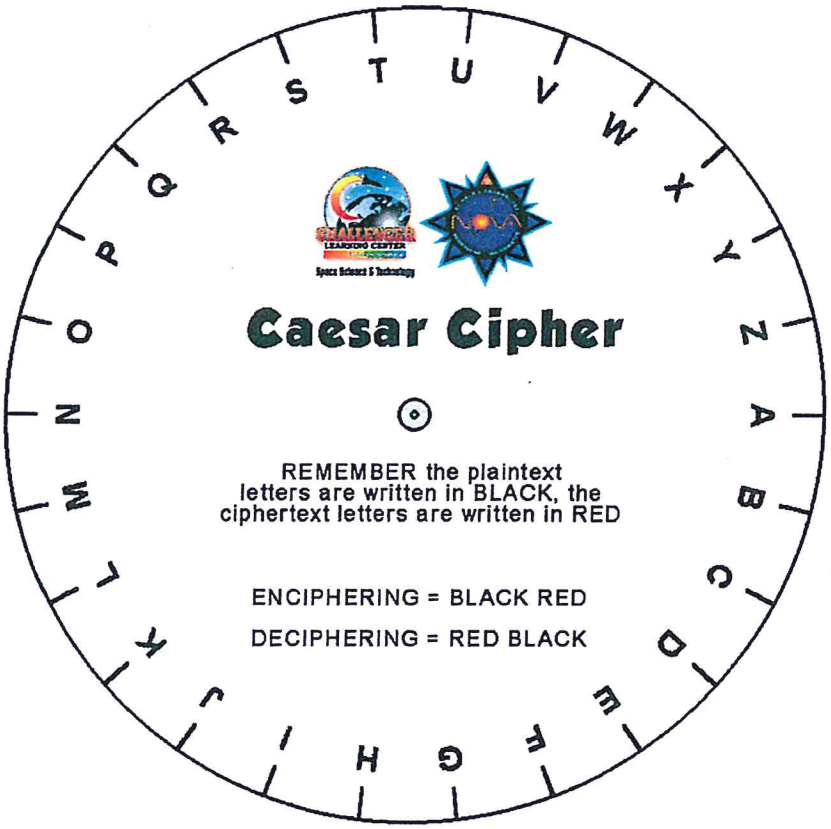
CONGRATULATIONS! You have created a Number Shift Cipher!

Decrypting a Number Shift Cipher

1. To begin decrypting the ciphertext, take the first number from the message and examine the number's two digits. The first digit is the row number and the second digit is the column number.
2. Write the letter that appears at the intersection of the specific row and column on the grid.
3. Continue decrypting the ciphertext until your message is revealed.

CONGRATULATIONS! You have learned how to decrypt a Number Shift Cipher!





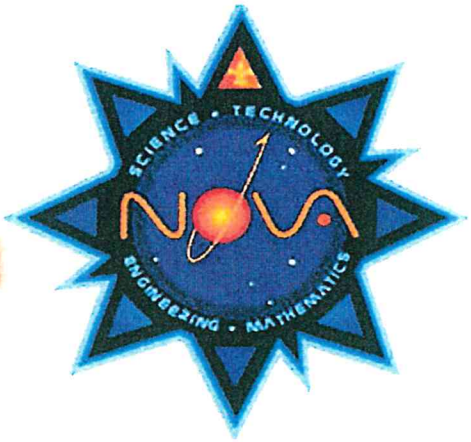
Caesar Cipher

REMEMBER the plaintext
letters are written in BLACK, the
ciphertext letters are written in RED

ENCIPHERING = BLACK RED

DECIPHERING = RED BLACK

HOW DOES MATH AFFECT DAILY LIFE?



Requirement (4.B.3) How Does Math Affect Daily Life?

Discuss with your counselor how math affects your everyday life.

When you buy a car, follow a recipe, or decorate your home, you're using math principles. People have been using these same principles for thousands of years, across countries and continents. Whether you're sailing a boat off the coast of Japan or building a house in Peru, you're using math to get things done.

How can math be so universal? First, human beings didn't invent math concepts; we discovered them. Also, the language of math is numbers, not English or German or Russian. If we are well versed in this language of numbers, it can help us make important decisions and perform everyday tasks. Math can help us to shop wisely, buy the right insurance, remodel a home within a budget, understand population growth, or even bet on the horse with the best chance of winning the race.

Mathematics is the only language shared by all human beings regardless of culture, religion, or gender. Pi is still approximately 3.14159 regardless of what country you are in. Adding up the cost of a basket full of groceries involves the same math process regardless of whether the total is expressed in dollars, rubles, or yen. With this universal language, all of us, no matter what our unit of exchange, are likely to arrive at math results the same way.

Other Requirements

Complete the remaining requirements per the instruction in the guidebook.

STEM-in-a-Box Experiment

How to Make A Number Shift Cipher

	1	2	3	4	5
1	A	B	C	D	E
2	F	G	H	I/J	K
3	L	M	N	O	P
4	Q	R	S	T	U
5	V	W	X	Y	Z

Encrypting a Number Shift Cipher (You will need the Polybius Grid)

1. Write down your **plaintext** message on a piece of paper.
2. Begin encrypting your message by locating the first letter of your plaintext message in the grid.
3. Write down the row number followed by the column number.
4. Continue until your entire message has been encrypted.
5. To make your message more secure, leave out the spaces between each word.

CONGRATULATIONS! You have created a Number Shift Cipher!

Decrypting a Number Shift Cipher

1. To begin decrypting the ciphertext, take the first number from the message and examine the number's two digits. The first digit is the row number and the second digit is the column number.
2. Write the letter that appears at the intersection of the specific row and column on the grid.
3. Continue decrypting the ciphertext until your message is revealed.

CONGRATULATIONS! You have learned how to decrypt a Number Shift Cipher!