



The Enigma Machine

Teacher Materials

Students learn about the importance of cryptography in World War II and experience a more advanced method of encrypting data and communications. Students will have hands-on practice manipulating a paper version of the German Enigma Machine and gain experience in its operation to decrypt messages encrypted with the Enigma Machine.

Students will understand the basic operation of the Enigma Machine, decode and encode various messages using the paper Enigma Machine.

Acknowledgements and License

This activity was contributed by Randy Henderson, McMillan Magnet School for UNO's TED 8006 course. Activity introduction taken from Wikipedia, https://en.wikipedia.org/wiki/Enigma_machine.

Lesson Details

Grade Level: 8–12th graders

Activity Length: 20-30 minutes

Format: Students working in groups of 3-4, materials for 2 groups

Connection to Standards

This activity contains content and practices addressing elements of the following CSTA K-12 Computer Science Standards (2017):

CSTA Std	Description
1A-AP-09	Model the way programs store and manipulate data by using numbers or other symbols to represent information.
2-NI-06	Apply multiple methods of encryption to model the secure transmission of information.
2-DA-07	Represent data using multiple encoding schemes.
2-IC-23	Describe tradeoffs between allowing information to be public and keeping information private and secure.

This activity contains content and practices addressing elements of the following Nebraska K-12 Technology Scope & Sequence Standards:

NE Tech Standard	Description
Computational Thinking 1	Create algorithms, or series of ordered steps, to solve problems.
Computational Thinking 3	Collect, analyze, and represent data effectively.
Computational Thinking 4	Demonstrate and understanding of how information is represented, stored, and processed.

Bin Materials Checklist

#	Description
2	"Enigma Machines"
6	Pencils
1	Pencil sharpener

Lesson Vocabulary Words

cryptography the practice and study of techniques used for securing communication and information from unattended readers, enemies or adversaries

plain text text that is not written in code; messages before they have been encoded or encrypted

cipher a secret or disguised way of writing; a code

rotors the individual cogs of letters that rotate to encode the letters

encoding/encrypting converting information or data into another system

key the initial setting of the Enigma Machine (what the three rotors need to be set to before encoding or decoding a message)

decoding/decrypting returning the encoded/ encrypted message back to its plain text form

Lesson Setup / Introduction

The students will read the brief history of the Enigma Machine and it's operation. Student will need to carefully read and follow the instructions on how to use the Enigma Machine before decoding any messages. **Please have the students decode the first message on the students sheet and have them check it!** If correct, the students can then use this knowledge to decode or break the messages on the student worksheet. If incorrect, students may need help in basic Enigma operation.

Connection to Computing

From Wikipedia, https://en.wikipedia.org/wiki/Computer_security: "Computer security, also known as cyber security or IT security, is the protection of computer systems from the theft or damage to their hardware, software or information, as well as from disruption or misdirection of the services they provide. Cyber security includes controlling physical access to the hardware, as well as protecting against harm that may come via network access, data and code injection. Also, due to malpractice by operators, whether intentional, accidental, IT security is susceptible to being tricked into deviating from secure procedures through various methods."

Assembly Instructions

Print enigma1.pdf and enigma2.pdf without any page scaling on the printer to ensure proper fit. Laminate, cut, and tape so they turn independently.

For the answer key on the worksheet to work, it is important to assemble the enigma machine in the following order from left to right when looking at the chip can:

- reflector B
- Rotor I
- Rotor II
- Rotor III
- Input/Output letters

Other combinations will produce a different cipher.

Further Related Resources

- Enigma Machine Description https://en.wikipedia.org/wiki/Enigma_machine
- Video at Khan Academy <http://bit.ly/khanenigma>
- Alan Turing
<http://www.iwm.org.uk/history/how-alan-turing-cracked-the-enigma-code>
- Enigma Machine Emulator <http://enigma.louisedade.co.uk/>

Answer Key

Encoded Text 1	Plain Text Message 1		Encoded Text 2	Plain Text Message 2
Example: BOX	Example: AIR			
OPC	THE		H	I
TEJ	OLD		ILZU X	HEART
MCW	DRY		QIKX LRKT	COMPUTER
FWI	EGG		JRGW CMK	SCIENCE
KDP	WAS		BQJ	AND
HRMV	ICKY		BHSD R	APPLE
OI	TO		VIEH B	ROCKS
FDH	EAT			

The Enigma Machine

Student Instructions

Introduction:

The **Enigma machines** were a series of electro-mechanical rotor cipher machines developed and used in the early- to mid-twentieth century to protect commercial, diplomatic and military communication. Enigma was invented by the German engineer Arthur Scherbius at the end of World War I. Early models were used commercially from the early 1920s, and adopted by the military and government services of several countries, most notably Nazi Germany before and during World War II.

To start, set up the Enigma machine:

- Set the enigma machine with A - A - A - A reading across all rotors to start. The reflector also must be set so that the gray bar lines up with the gray bar on the Input//Output strip (for A). This shows the start position of your Enigma machine and lets you track the turnover positions of the rotors.
- Turn the rotors so that the three letters of your message key are in line with the grey bars; for practice use the key of **A B C**.

To operate your Enigma machine, for each letter in your message:

- Turn just the right-hand rotor one step **towards you** (so the letter in line with the grey bar becomes the next one alphabetically); make sure that the other rotors *and* the Input/Output cylinder stay still. *You must do this before you read off the letter (even the first one!)*
- Find the letter from your message on the Input/ Output cylinder at the right-hand side, and trace the line from it through all three rotors, in to the reflector, out again back through all three rotors and into the Input/ Output cylinder again. Write down the letter at which you end up.
- For practice, try decoding this message:
– **A E F A E J X X B N X Y J T Y**
Decoded message:

If you got it right, you should have written down one correct English word!

Challenge: Enigma Paper Machine Cryptography Worksheet

For more advanced Enigma operation continue below.

Rotor Turnover (Advanced)

When the right-hand rotor turns one step, at some positions other rotors turn over as well, which makes the scrambling harder to predict. In the example above we chose the message key A B C with a short message so that no turnovers occurred.

To handle turnover correctly, we need to add to our instructions above for turning the rotors, based on the letters showing in line with the grey bars:

- If the letters on the middle rotor is shaded grey, turn **all three** rotors one step towards you.
- *otherwise*, if the letter on the right-hand rotor is shaded grey, turn the **middle and right-hand** rotors one step towards you.
- *otherwise*, turn just the right-handed rotor one step towards you.

The shading of the letter on the left-handed rotor doesn't matter, it would only come into play if that rotor was in a different place in the order.

For practice, try deciphering this message with the rotors in the same order as our basic example above (I, II, III) and with message key **A B R**:

- **M A B E K G Z X S G**
Decoded message:

When you've finished, you should have written down two correct English words, and your rotors should finish at positions A C B.

Hints:

- Before the turn see if there is a grey letter on any of the rotors inline with the end grey bars. If not, follow the encoding.
- ** Remember: Turns happen before you read the letter.
 - No gray bar: Normal operation, turn one then decode letter.
- If there is a gray bar
 - Yes there is a gray bar: then turn the middle once and rotor 3 twice, then decode the letter.



Hand-Outs

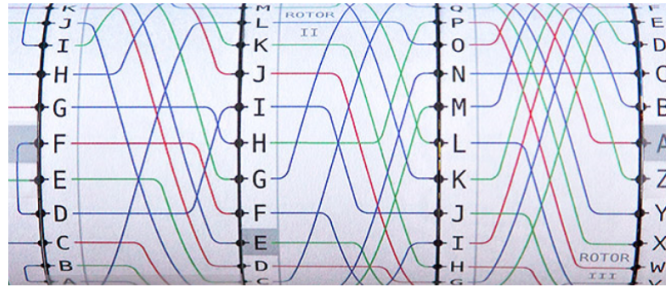


Figure 1: Photo taken from Sotheby's/BNPS <https://tinyurl.com/y773nqn6>

Directions- Test your rotor:

- Set all of the rotors to the key of AAA. Decrypt the following three letter groups.
- Remember to move the right rotor one letter BEFORE encrypting each letter.
- Remember to restart the rotors to AAA for each three-letter group.

The first column of decrypts are mostly three-letter words. The example: BOX decrypts to AIR.

The second column is more advanced code using a combination of multiple letter words.

Cypher Text 1	Plain Text Message 1		Cypher Text 2	Plain Text Message 2
Example: BOX	Example: AIR			
OPC			H	
TEJ			ILZU X	
MCW			QIKX LRKT	
FWI			JRGW CMK	
KDP			BQJ	
HRMV			BHSD R	
OI			VIEH B	
FDH				

Resupply

- Sharpen and/or Restock Pencils