

## On the Subject of The Ultimate Cycle

*How much security does one word need?*

This module consists of a screen, eight dials with red labels, and a QWERTY keyboard.

The labels on the dials, when decrypted and read from left to right, spell out an eight letter word.

The word has been encrypted through a series of ciphers, indicated by the direction each dial is pointing, from left to right.

Once deciphered, find the word in the table below, the word written below it is the word that should be entered.

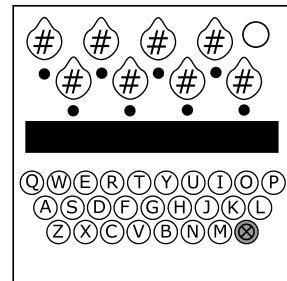
Apply the same sequence of encryptions to the response word, and type out the encrypted response word using the keys.

The word is automatically submitted when eight keys are pressed.

The red button can be pressed at any time before the eighth key is pressed to cancel the input.

Inputting any of the eight letters incorrectly will cause a strike to be issued and reset the module.

**Note:** Unless stated otherwise, any reference to a letter's alphabetic position starts at A = 1. Similarly, any reference to the position of a dial starts from the leftmost dial = 1.



## N: Atbash Logic Cipher

### Logic component

For each dial: if the number of  $45^\circ$  rotations, starting from north, is odd, then the bit given by the dial is 1. Otherwise, it is 0.

Form four pairs of bits by grouping the bits corresponding to adjacent pairs of dials from left to right.

Form another four pairs of bits by grouping the bits corresponding to adjacent pairs of dials in reading order.

Each of the eight pairs of bits correspond to each of the eight dials from left to right.

Using the operator corresponding to the position of the north pointing dial, find the truth values of each pair; the encrypted letter depends on whether each is true or false.

	AND	OR	XOR	$\Rightarrow$	NAND	NOR	XNOR	$\Leftarrow$
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	Letter	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
Truth Value	True	U	F	Z	W	D	B	V	C	L	S	H	I	J	M	N	Q	G	X	Y	K	T	E	O	P	R	A
False	N	V	Y	P	W	A	H	O	Q	C	M	U	G	F	D	I	R	L	T	X	B	S	K	J	Z	E	

### Atbash component

Each letter in the word is swapped with the letter with the same alphabetic position in the reversed alphabet.

That is, a letter with alphabetic position X will become the letter with alphabetic position  $27 - X$ .

If the LED below the north pointing dial is lit, the Atbash cipher is applied to the input of the Logic cipher.

Otherwise, the Atbash cipher is applied to the output of the Logic cipher.

## NE: Caesar Cipher

Each letter in the word has been shifted forwards through the alphabet by the position of the dial corresponding to this cipher.

If the LED corresponding to this dial is lit, each letter is then shifted further by the number of  $45^\circ$  rotations, starting from north, to the direction each dial is pointing.

Otherwise, each letter is then shifted backwards through the alphabet by the number of  $45^\circ$  rotations, starting from north, to the direction each dial is pointing.

## E: Playfair Cipher

The indexing of the lists start at zero.

- If the last dial is pointing south, use the word corresponding to the number of 45° rotations, starting from north, of the first dial.
- Otherwise, the number of rotations, starting from north, of the next dial corresponds to which of the words in the lists below is the keyword for this cipher.
  - If there are less than three unique\* ports on the bomb, use the keyword from List A.
  - Otherwise, use the keyword from List B.
- The keyword gives the first ten letters of the keysquare.
  - If the LED corresponding to this cipher is unlit, the keyword is entered into the keysquare in reading order.
  - Otherwise, the keyword is entered into the keysquare in reverse reading order.
- The remaining 15 letters fill the rest of the keysquare in alphabetical order, excluding X, which is never used.
- The word is split into four pairs of letters.
- Each pair of letters is altered:
  - If both letters are the same, the encrypted pair is two of the letter diametrically opposite in the keysquare.
  - Otherwise, if both letters belong to the same row of the keysquare, shift both letters one space to the right along the row.
  - Otherwise, if both letters belong to the same column of the keysquare, shift both letters once space down the column.
  - Otherwise, the letters lie on diagonally opposite corners of a rectangle, the encrypted pair consists of the letters in the horizontally opposite corners from the original pair.

\*A port is unique if there is only one of its type on the bomb.

List A: ALGORITHMS, AUTHORIZED, BLUEPRINTS, DESPICABLY, FORMIDABLE, HYPERBOLIC, IMPORTANCE, LABYRINTHS

List B: WANDERLUST, VANQUISHED, ULTRASONIC, SCRAMBLING, PRECAUTION, OSTRACIZED, METHODICAL, MAGNITUDES

### Important:

- If the pair of letters is XX, the pair is unchanged by the cipher.
  - If the pair of letters is either X# or #X, where # is not X, the X is changed to the other letter, forming a double letter pair, and enciphered normally.
- Then, the new letter is changed back to an X.

## SE: Pigpen Cipher

Each letter is translated using one of the two pigpen ciphers below.

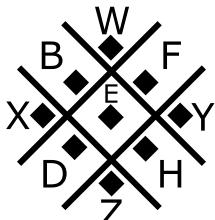
Starting from north, the pigpen characters are rotated to face the direction the dial is pointing. The rotated pigpen characters are then translated back, as though they are still facing north, to produce the encrypted letter.

If the LED corresponding to this cipher is unlit, use cipher I. Otherwise, use cipher II.

### Cipher I

A	B	C
D	E	F
G	H	I

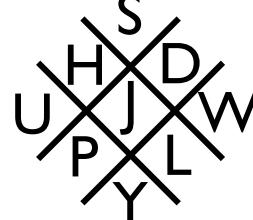
J	K	L
M	N	O
P	Q	R



### Cipher II

A	C	E
G	I	K
M	O	Q

B	D	F
H	J	L
N	P	R



## S: Two Square Cipher

The indexing of the lists start at 0. For this cipher, the leftmost dial has a position of 0.

- The two lists give the keywords for two 5x5 keysquares, the keyword from List A is used for the first keysquare and the keyword from List B is used for the second:
  - If the numbers in the serial number add up to more than 9, the keyword in List A is given by the position of dial and the keyword in List B is given by the number of 45° rotations, starting from north, of the **previous** dial.
  - Otherwise, the keyword in List B is given by the position of dial and the keyword in List A is given by the number of 45° rotations, starting from north, of the **previous** dial.
  - If the first dial is pointing south, the 'previous' dial is the last dial.
- These keywords fill the first two rows of their respective keysquares in reading order. The remaining 15 letters of each keysquare fill them in alphabetical order, excluding X, which is never used.
- If the LED below the south pointing dial is lit, the keysquares are arranged horizontally, with the first keysquare to the left of the second. Otherwise, the keysquares are arranged vertically, with the first keysquare above the second.
- The word is split into four pairs of letters. From each pair, the first letter is found in the first keysquare and the second letter is found in the second keysquare.
  - If both letters line up horizontally, they are both shifted one space to the right in their respective keysquares.
  - If both letters line up vertically, they are both shifted one space down their respective keysquares.
  - Otherwise, the letters lie on diagonally opposite corners of a rectangle between the two keysquares. The encrypted pair consists of the letters in the horizontally opposite corners of the rectangle.

List A: AFTERSHOCK, DESTROYING, DUPLICATES, FARSAIGHTED, GRACIOUSLY, INFAMOUSLY, NIGHTMARES, PALINDROME

List B: DOWNSTREAM, EMORDNILAP, FLASHPOINT, INTRODUCES, PATHFINDER, QUADRICEPS, TRAPEZOIDS, WAVERINGLY

### **Important:**

- If the pair of letters is **XX**, the pair is unchanged by the cipher.
- If the pair of letters is either **X#** or **#X**, where # is not X, the X is changed to the other letter, forming a double letter pair, and enciphered normally. Then, the new letter is changed back to an X.

## SW: Monoalphabetic Substitution Cipher

The position of the dial corresponds to which of the eight words in the list below is the keyword for this cipher:

DOCUMENTARILY, FLAMETHROWING, FLOWCHARTINGS, HYDROMAGNETIC, METALWORKINGS, MULTIBRANCHED, TROUBLEMAKING, UNPREDICTABLY

If the LED is unlit, the remaining thirteen letters of the alphabet are left in alphabetical order. Otherwise, the remaining thirteen letters are positioned in reverse alphabetical order.

- If there are an even number of batteries, the keyword precedes the remaining letters to construct a cipher alphabet.
- Otherwise, the keyword follows the remaining letters to construct a cipher alphabet.

Each letter of the alphabet is mapped onto the letter of the cipher alphabet with the same alphabetic position.

The letters in the word change accordingly with these mappings.

**W: Hill Cipher**

If there are more lit than unlit indicators, the keyword for this cipher belongs to list A. Otherwise the keyword for this cipher belongs to list B.

The keyword used depends and the rotations of the dials adjacent to the one corresponding to this cipher:

The indexing of the lists start at zero.

- If the first dial is pointing west, use the keyword corresponding to six plus the number of 45° rotations, starting from north, of the second dial.
- If the last dial is pointing west, use the keyword corresponding to six plus the number of 45° rotations, starting from north, of the seventh dial.
- Otherwise, use the keyword corresponding to the sum of the numbers of 45° rotations, starting from north, of the two dials adjacent to this one.

**List A:** AEON, COPY, EACH, GOOD, IOTA, KILO, MARK, ONCE, QUIT, RIOT, SYNC, UNDO, WORK, YEAR, ZEAL

**List B:** BOMB, BUSY, DICE, FAUX, HUSK, JUKE, LIMA, LOCI, NAME, PUSH, RISE, TASK, VOID, XYST, ZOOM

The alphabetic positions of the letters in the keyword modulo 26 form the entries of a 2x2 square keymatrix in reading order.

If the LED corresponding to this cipher is lit, the matrix is then transposed, swapping its top-right and bottom-left entries.

The word to be enciphered is broken into four pairs of letters and their alphabetic positions modulo 26 form entries in 2x1 vectors.

The vectors are multiplied by the keymatrix and taken modulo 26 to obtain the alphabetic positions of the encrypted pairs of letters.

(Because Z has an alphabetic position of 26, its corresponding entry in the encrypted vector is zero.)

**NW: Permutation Cipher**

The following rule is used to uniquely assign each dial from left to right with a number from 1 to 8:

- If unassigned, assign the number of 45° rotations of the dial, starting from north, plus one.
- Otherwise, if the LED corresponding to the dial is lit, assign the highest unassigned number to it.
- Otherwise, assign the lowest unassigned number to it.

Each number in this sequence from left to right corresponds to a letter in the word in reading order.

If the LED corresponding to this cipher is lit, the word is rearranged such that the numbers corresponding to each letter are in ascending order

Otherwise, the word is rearranged such that the numbers corresponding to each letter are in descending order.

The rearranged word is then cyclically shifted such that the first letter of the encrypted word is the letter whose corresponding number is the position of the dial corresponding to this cipher.

Keyword Table

ADVANCED	ADVERTED	ADVOCATE	ADDITION	ALLOCATE	ALLOTYPE	ALLOTTED	ALTERING
PROGRESS	ZYGOTENE	QUARTICS	LINKAGES	QUICKEST	ORDERING	UNDOINGS	ZUGZWANG
BINARIES	BINORMAL	BINOMIAL	BILLIONS	BULKHEAD	BULLHORN	BULLETED	BULWARKS
YOKOZUNA	COMMANDO	GLOOMING	TRICKIER	GATEWAYS	INCOMING	ZYGMATA	FORMULAE
CIPHERED	CIRCUITS	CONNECTS	CONQUERS	COMMANDO	COMPILER	COMPUTER	CONTINUE
BULKHEAD	RELATION	LINKWORK	NANOTUBE	MONOTONE	YIELDING	ILLUMINE	KILOBYTE
DECRYPTS	DECEIVED	DECIMATE	DIVISION	DISCOVER	DISCRETE	DISPATCH	DISPOSAL
NANOBOTS	QUINTICS	ZIGZAGGY	MONOMIAL	ULTERIOR	KNUCKLED	UNDERWAY	ULTRARED
ENCIPHER	ENCRYPTS	ENCODING	ENTRANCE	EQUALISE	EQUATORS	EQUATION	EQUIPPED
JUNKYARD	QUADRANT	TRIANGLE	RELAYING	NANOGRAM	CONNECTS	INDICATE	BINORMAL
FINALISE	FINISHED	FINDINGS	FINNICKY	FORMULAE	FORTUNES	FORTRESS	FORWARDS
DISCRETE	JUNCTION	KILOWATT	ROTATION	POSITRON	DISPATCH	ENCIPHER	STANDOUT
GARRISON	GARNERED	GATEPOST	GATEWAYS	GAUNTLET	GAMBLING	GATHERED	GLOOMING
STOCKADE	FINDINGS	ADVANCED	JOURNEYS	STOPPING	LANDMARK	EQUATION	VICELESS
HAZARDED	HAZINESS	HOTLINKS	HOTHEADS	HUNDREDS	HUNKERED	HUNTSMAN	HUNTRESS
DISCOVER	JUNCTURE	TOGETHER	GARRISON	WHATNOTS	DIVISION	TOGGLING	YEASAYER
INCOMING	INDICATE	INDIRECT	INDIGOES	ILLUDING	ILLUSION	ILLUSORY	ILLUMINE
VENOMOUS	FORTUNES	OBSERVED	QUITTERS	HUNKERED	HOTHEADS	TOMOGRAM	KNOWABLE
JIGSAWED	JIMMYING	JOURNEYS	JOUSTING	JUNCTURE	JUNCTION	JUNKYARD	JUDGMENT
YEARNING	TRIGONAL	VOLITION	DECRYPTS	LABELING	STARTING	OCTUPLES	ROTATORS
KILOWATT	KILOVOLT	KILOBYTE	KINETICS	KNOCKING	KNOCKOUT	KNOWABLE	KNUCKLED
POSITIVE	BILLIONS	WHATEVER	FINALISE	ENCRYPTS	OBSTACLE	ENCODING	ADVOCATE
LANGUAGE	LANDMARK	LIMITING	LINEARLY	LINGERED	LINKAGES	LINKWORK	LABELING
CONQUERS	EQUATION	GATEPOST	ILLUSION	QUIRKISH	NUMERATE	STANDARD	POSTSYNC
MONOGRAM	MONOLITH	MONOMIAL	MONOTONE	MULTITON	MULTIPLY	MULCTING	MULLIGAN
HUNTRESS	WINNABLE	ZYMOLOGY	ILLUSORY	VOLATILE	TOMAHAWK	OCTANGLE	ADVERTED

**Keyword Table cont.**

NANOBOTS	NANOGRAM	NANOWATT	NANOTUBE	NUMBERED	NUMEROUS	NUMERALS	NUMERATE
ZIPPERED	STOCCATA	VENDETTA	LINGERED	FINNICKY	JUDGMENT	HUNDREDS	ILLUDING
OCTUPLES	OCTANGLE	ORDERING	ORDINALS	OBSERVED	OBSCURED	OBSTRUCT	OBSTACLE
KNOCKING	WINGDING	UNDERLIE	LINEARLY	TRIGGERS	PROJECTS	ALLOTYPE	YIELDERS
PROGRESS	PROJECTS	PROPHASE	PROPHECY	POSTSYNC	POSSIBLE	POSITRON	POSITIVE
JIGSAWED	KILOVOLT	ALLOTTED	RELATIVE	PROPHASE	COMPILER	LIMITING	NANOWATT
QUADRANT	QUADRICS	QUARTILE	QUARTICS	QUICKEST	QUIRKISH	QUINTICS	QUITTERS
YELLOWED	MULCTING	GATHERED	WEAKENED	WHATNESS	HAZINESS	REVOLVED	ENTRANCE
REVERSED	REVOLVED	REVEALED	ROTATION	ROTATORS	RELATION	RELATIVE	RELAYING
FORTRESS	WHATSITS	BULLHORN	GARNERED	INDIGOES	LANGUAGE	CIRCUITS	VOLTAGES
STARTING	STANDARD	STANDOUT	STANZAIC	STOCCATA	STOCKADE	STOPPING	STOPWORD
REVERSED	JIMMYING	DECEIVED	QUARTILE	GAUNTLET	HAZARDED	MULTIPLY	ZYMOGRAM
TRICKIER	TRIGONAL	TRIGGERS	TRIANGLE	TOMOGRAM	TOMAHAWK	TOGLLING	TOGETHER
MULLIGAN	ZIGGURAT	ALLOCATE	NUMERALS	BULWARKS	BINARIES	INDIRECT	REVEALED
UNDERRUN	UNDERWAY	UNDERLIE	UNDOINGS	ULTERIOR	ULTIMATE	ULTRARED	ULTRAHOT
JOUSTING	VICINITY	QUADRICS	MONOLITH	ORDINALS	KNOCKOUT	NUMEROUS	STOPWORD
VENOMOUS	VENDETTA	VICINITY	VICELESS	VOLITION	VOLTAGES	VOLATILE	VOLUMING
UNDERRUN	DISPOSAL	WEAPONED	HUNTSMAN	BULLETED	ALTERING	MONOGRAM	POSSIBLE
WEAKENED	WEAPONED	WINGDING	WINNABLE	WHATEVER	WHATNESS	WHATNOTS	WHATSITS
EQUALISE	OBSTRUCT	COMPUTER	STANZAIC	DECIMATE	EQUIPPED	BINOMIAL	YEARLONG
YELLOWED	YEARLONG	YEARNING	YEASAYER	YIELDING	YIELDERS	YOKOZUNA	YOURSELF
CIPHERED	CONTINUE	KINETICS	FORWARDS	ADDITION	FINISHED	GAMBLING	MULTITON
ZIPPERED	ZIGGURAT	ZIGZAGGY	ZUGZWANG	ZYgomata	Zygogene	Zymology	Zyogram
VOLUMING	ULTIMATE	HOTLINKS	NUMBERED	PROPHECY	YOURSELF	ULTRAHOT	OBSCURED