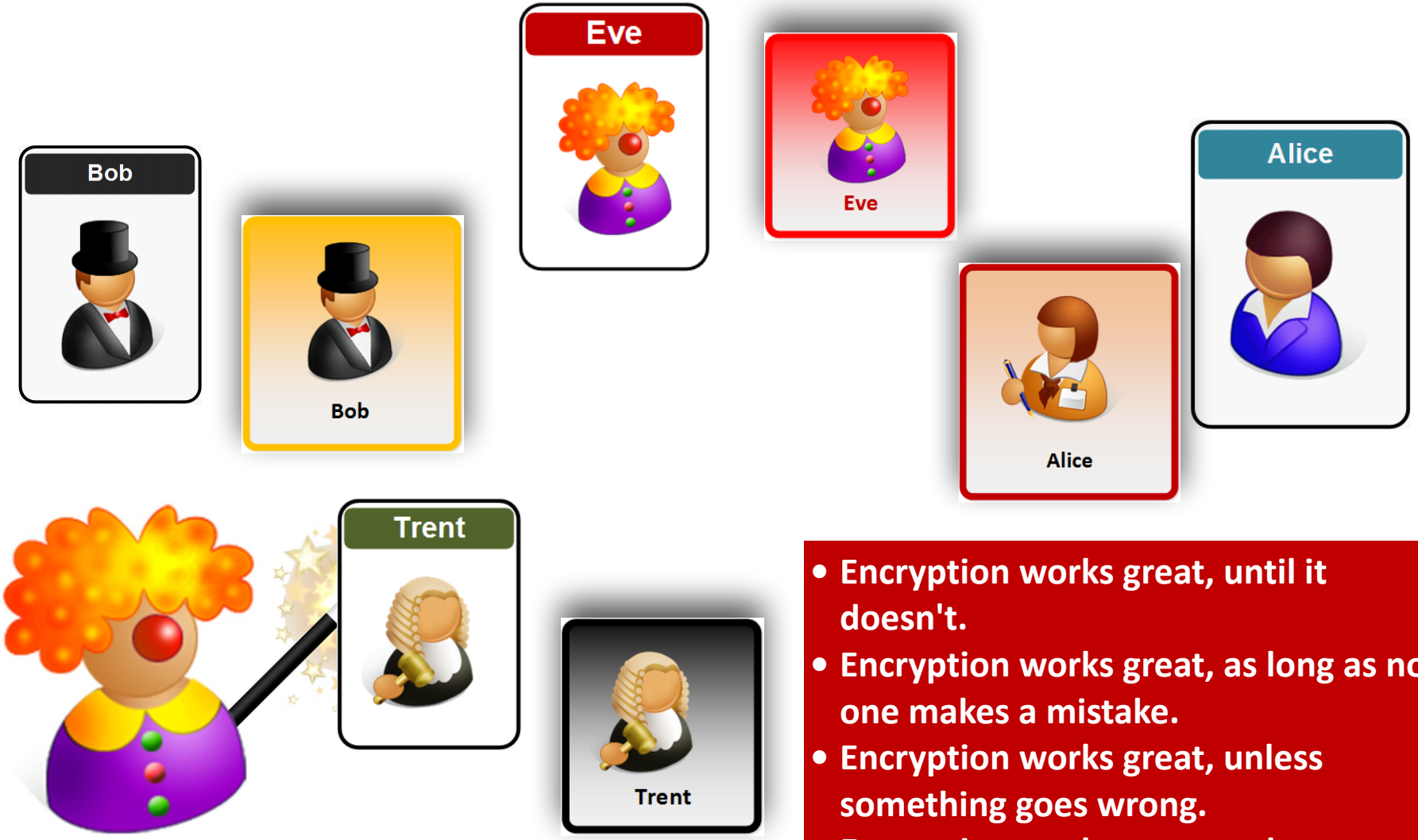
Cryptography Fundamentals

Traditional ciphers.
Frequency Analysis.
Operators and GCD.
Encoding.
Big Integers.
Random Numbers.
Key-based Encryption.

Prof Bill Buchanan
http://asecuritysite.com/encryption

Encryption



- Encryption works great, until it doesn't.
- Encryption works great, as long as no one makes a mistake.
- Encryption works great, unless something goes wrong.
- Encryption works great, as long as everything works right.

Bruce Schneier

Twofish,
Blowfish

Vincent Rijmen
and Joan Daemen

AES

Modern private
key encryption

Rivest, Shamir
& Aldeman

Public-k
encrypt

Ron
Rivest

Hashing

Whitfield
Diffie

Key
interchange

Phil
Zimmerman

PGP
Encryption

Author: Prof Bill Bucha

Meet the Cast

Meet the Cast

Advanced Crypto

1. Ciphers and Fundamentals

Ciphers.

http://asecuritysite.com/crypto

Author: Prof Bill Buchanan

Quilt codes

Flying geese

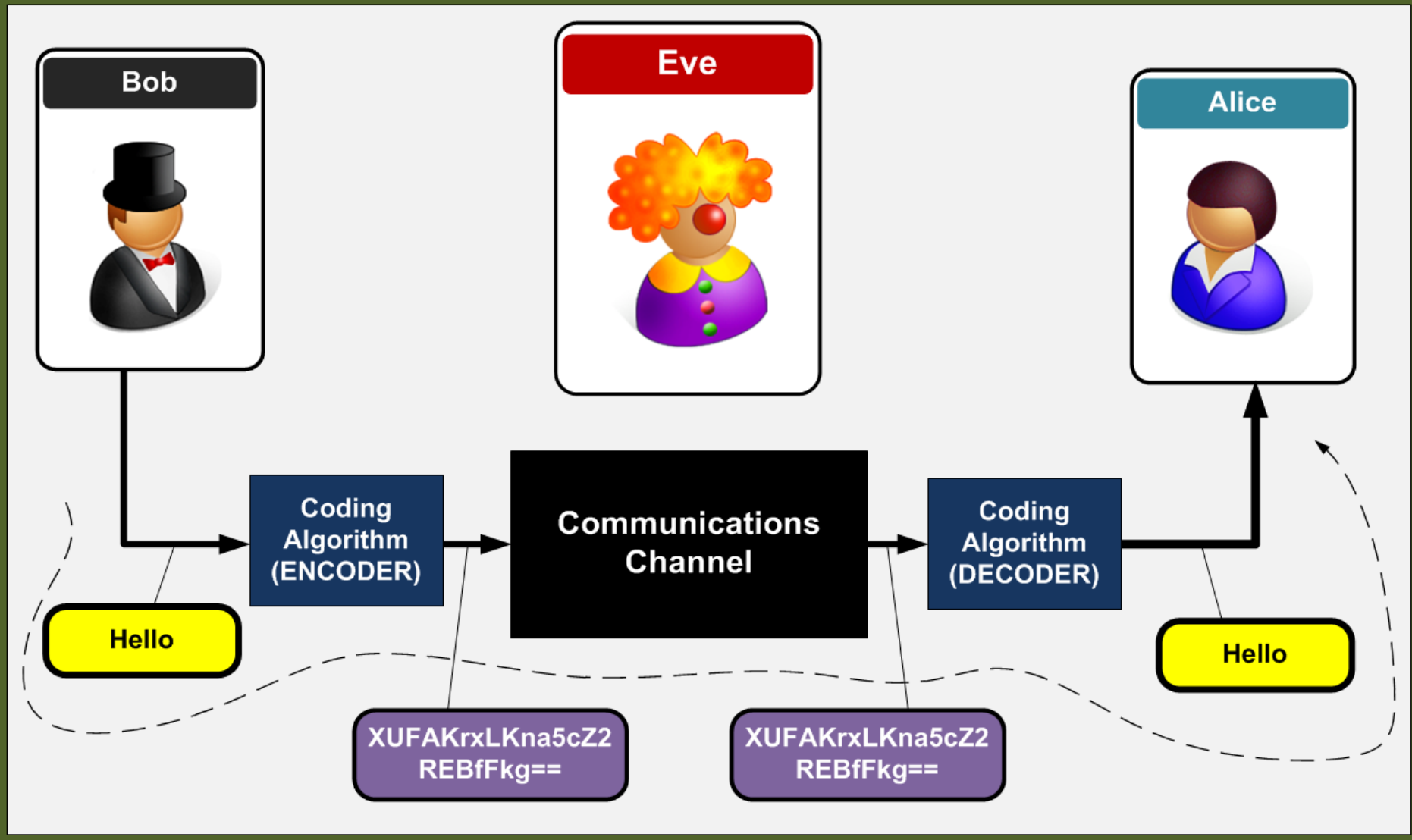
Sailboat

Smoke signals

Microfiche

Navajo Code Talkers

Author: Prof Bill Buchanan


Bob
Eve
Alice
Coding Algorithm (ENCODER)
Communications Channel
Coding Algorithm (DECODER)
Hello
XUFAKrxLKna5cZ2 REBfFkg==
XUFAKrxLKna5cZ2 REBfFkg==
Hello

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	(– –··)				

Plaintext h e l l o e v e r y o n e

Morse: .... . .-.. .-.. --- . ...- . .-. -.-- --- -. .

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

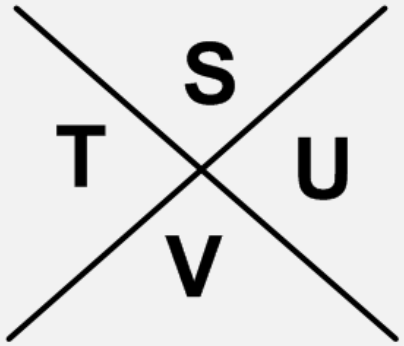
H	E	L	L	O
23	15	32	32	35

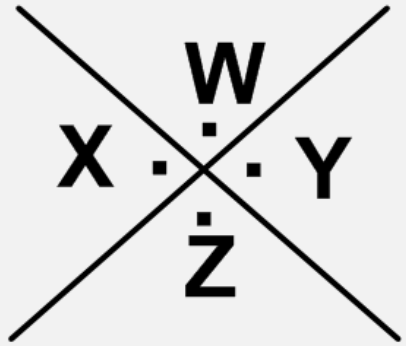
Polybius (Greek historian, ~200BC)

Author: Prof Bill Buchanan

A	B	C
D	E	F
	H	I

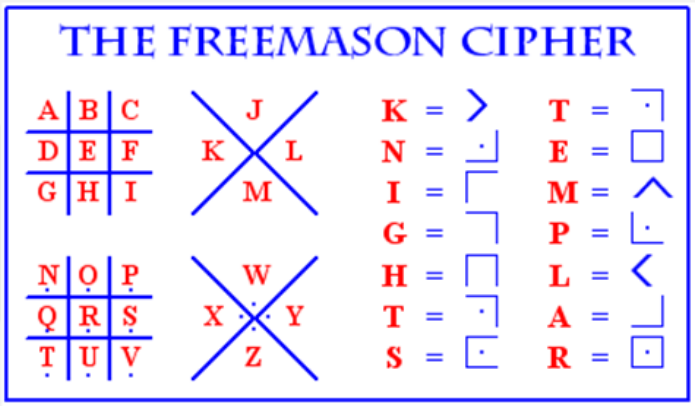
J	K	L
M	N	O
P	Q	R





Headstone of James Leeson (1792)

THE FREEMASON CIPHER



	A	D	F	G	V	X
A	8	p	3	d	1	n
D	l	t	4	o	a	h
F	7	k	b	c	5	z
G	j	u	6	w	g	m
V	x	s	v	i	r	2
X	9	e	y	0	f	q

Invented by Fritz Nebel, in WW1

FD VG VV FD FG DV DA AG XF

Charles Wheatstone

Lord Playfair

Code: **NAPIERUN**

Write out the 5x5 matrix, and do not repeat characters (get rid of Q and J):

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

AT	TA	CK
NAPIE	NAPIE	NAPIE
RUNBC	RUNBC	RUNBC
DFGHK	DFGHK	DFGHK
LMOST	LMOST	LMOST
VWXYZ	VWXYZ	VWXYZ

ME	EM	KT

Rules:

1. If the are in different columns, takes from the rectangle defined between them and pick off the opposite ends.
2. If the are in the same column, select the letter one below (and wrap-round if necessary).

Caesar

Mark Antony

Cleopatra

Plaintext

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

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

Ciphertext

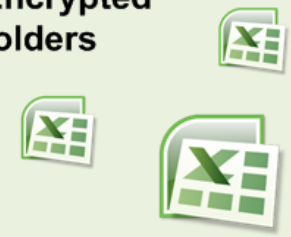
K H O O R

2011, **Rajib Karim**, - a greater threat that Bin Laden - a Software Engineer for British Airways, had a massive plot to blow up an in-air transatlantic jet.

Used Excel documents with Caeser codes, instead of PGP (because 'kaffirs' - non-believers – knew about PGP)

Protected by a password

Encrypted folders



Plaintext

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

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

Ciphertext

K H O O R

Caesar

Mark Antony

Cleopatra

Plaintext

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

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

Ciphertext

L Q N Z D O O

Caesar

Mark Antony

Cleopatra

Plaintext

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

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

Ciphertext

L Q N Z D O O

$4x10^{26}$ code mappings

26! = 26×25×24× …. ×2×1 = 403,291,461,126,605,635,584,000,000 codes

Author: Prof Bill Buchanan

ONR ECRYAPFJ FDAO PFOXADRT NPM TGOG UGD LR RDUCIEORT JP ONGO AO UGDDPO LR YARMRT LI GDIPDR AO MGJ DPO ADORDTRT QCPK. MAON ECAYGOR-SRI RDUCIEOAPD, LPL GDT GXAUR FJR ONR JGKR JRUCRO SRI OP RDUCIEO GDT TRUCIEO ONR KRJJGZR. ONRD, FJADZ G SRI ADORCUNGDZR KRONPT JFUN GJ TAQQAR-NRXXKGD, LPL GDT GXAUR UGD ZRDRCGOR ONR JGKR JRUCRO SRI, RYRD AQ RYR AJ XAJORDADZ OP ONRAC UPKKFDAUGOAPDJ. MAON EFLXAU-SRI RDUCIEOAPD, LPL GDT GXAUR TP DPO NGYR ONR JGKR ECPLXRK, GJ GXAUR UGD GTYRCOAJR NRC EFLXAU SRI JP ONGO LPL UGD FJR AO OP RDUCIEO UPKKFDAUGOAPDJ OP NRC. ONR PDXI SRI ONGO UGD TRUCIEO ONR UPKKFDAUGOAPDJ AJ GXAUR'J ECAYGOR SRI (MNAUN, NPERQFXXI, RYR UGDDPO ZRO NPXT PQQ). MR DPM, ONPFZN, NGYR QPFC QFCONRC ECPLXRKJ:- NPM TP MR SDPM ONGO AO MGJ CRGXXI LPL MNP JRDO ONR TGOG, GJ GDIPDR UGD ZRO GXAUR'J EFLXAU SRI, GDT ONFJ ECRORDT OP LR LPL? - NPM UGD MR ORXX ONGO ONR KRJJGZR NGJ DPO LRRD OGKERCRT MAON? - NPM TPRJ LPL TAJOCALFOR NAJ EFLXAU SRI OP GXAUR, MAONPFO NGYADZ OP EPJO AO PDOP G MRL JAOR PC QPC LPL OP LR PD-XADR MNRD GXAUR CRGTJ ONR KRJJGZR? - MNP UGD MR CRGXXI OCFJO OP ECPERCXI GFONRDOAUGOR LPL? PLYAPFJXI MR UGD'O OCFJO LPL OP GFONRDOAUGOR ONGO NR CRGXXI AJ LPL. ONRJR WFRJOAPDJ MAXX LR GDJMRCRT AD ONAJ FDAO, GJ MR MAXX XPPS GO ONR FJGZR PQ NGJNADZ OP QADZRC-ECADO TGOG, GDT ONRD NPM LPL'J ECAYGOR SRI UGD LR FJRT OP GFONRDOAUGOR NAKJRXQ. QADGXXI, AO MAXX XPPS GO ONR MGI ONGO G EFLXAU SRI UGD LR TAJOCALFORT, FJADZ TAZAOGX URCOAQAUGORJ, MNAUN UGD UGCCI RDUCIEOAPD SRI. ONAJ UNGEORC MAXX JNPM ONR AKEPCOGDUR PQ GFONRDOAUGOAPD GDT GJJFCGDUR, GXPDZ MAON UPDQATRDOAGXAOI (QAZFCR 4.1), GDT ONR FJGZR PQ LAPKROCAUJ.

Letters (%)		Digrams (%)		Trigrams (%)		Words (%)	
E	13.05	TH	3.16	THE	4.72	THE	6.42
T	9.02	IN	1.54	ING	1.42	OF	4.02
O	8.21	ER	1.33	AND	1.13	AND	3.15
A	7.81	RE	1.30	ION	1.00	TO	2.36
N	7.28	AN	1.08	ENT	0.98	A	2.09
I	6.77	HE	1.08	FOR	0.76	IN	1.77
R	6.64	AR	1.02	TIO	0.75	THAT	1.25
S	6.46	EN	1.02	ERE	0.69	IS	1.03
H	5.85	TI	1.02	HER	0.68	I	0.94
D	4.11	TE	0.98	ATE	0.66	IT	0.93
L	3.60	AT	0.88	VER	0.63	FOR	0.77
C	2.93	ON	0.84	TER	0.62	AS	0.76
F	2.88	HA	0.84	THA	0.62	WITH	0.76
U	2.77	OU	0.72	ATI	0.59	WAS	0.72
M	2.62	IT	0.71	HAT	0.55	HIS	0.71
P	2.15	ES	0.69	ERS	0.54	HE	0.71
Y	1.51	ST	0.68	HIS	0.52	BE	0.63
W	1.49	OR	0.68	RES	0.50	NOT	0.61
G	1.39	NT	0.67	ILL	0.47	BY	0.57
B	1.28	HI	0.66	ARE	0.46	BUT	0.56
V	1.00	EA	0.64	CON	0.45	HAVE	0.55
K	0.42	VE	0.64	NCE	0.43	YOU	0.55
X	0.30	CO	0.59	ALL	0.44	WHICH	0.53
J	0.23	DE	0.55	EVE	0.44	ARE	0.50
Q	0.14	RA	0.55	ITH	0.44	ON	0.47
Z	0.09	RO	0.55	TED	0.44	OR	0.45

Author: Prof Bill Buchanan

Plaintext:	abcdefghijklmnopqrstuvwxyz
Scrambled code:	GLUTRQZNABSXKDPEWCJOFYMVIH

Gen another

Message:

```
The previous unit outlined how data can be encrypted so that it cannot be viewed by
anyone that it was not intended from. With private-key encryption, Bob and Alice
use the same secret key to encrypt and decrypt the message. Then, using a key
interchange method such as Diffie-Hellman, Bob and Alice can generate the same
secret key, even if Eve is listening to their communications. With public-key
```

Convert

Encoded:

```
ONR ECRYAPFJ FDAO PFOXADRT NPM TGOG UGD LR RDUCIEORT JP ONGO AO UGDDPO LR YARMRT LI
GDIPDR ONGO AO MGJ DPO ADORDTRT QCPK. MAON ECAYGOR-SRI RDUCIEOAPD, LPL GDT GXAUR
FJR ONR JGKR JRUCRO SRI OP RDUCIEO GDT TRUCIEO ONR KRJJGZR. ONRD, FJADZ G SRI
ADORCUNGDZR KRONPT JFUN GJ TAQQAR-NRXXKGD, LPL GDT GXAUR UGD ZRDRCGOR ONR JGKR
JRUCRO SRI, RYRD AQ RYR AJ XAJORDADZ OP ONRAC UPKKFDAUGOAPDJ. MAON EFLXAU-SRI
```

Frequency Analysis of Text

This table shows the occurances of the letters in the text (ignoring the case of the letters):

a	b	c	d	e	f	g	h	i	j	k	l	m
95 [7.1%]	0 [0.0%]	51 [3.8%]	90 [6.8%]	28 [2.1%]	38 [2.9%]	105 [7.9%]	0 [0.0%]	35 [2.6%]	66 [5.0%]	21 [1.6%]	45 [3.4%]	34 [2.6%]
n	**o**	**p**	**q**	**r**	**s**	**t**	**u**	**v**	**w**	**x**	**y**	**z**
72 [5.4%]	138 [10.4%]	90 [6.8%]	19 [1.4%]	159 [11.9%]	16 [1.2%]	35 [2.6%]	59 [4.4%]	0 [0.0%]	1 [0.1%]	50 [3.8%]	13 [1.0%]	19 [1.4%]

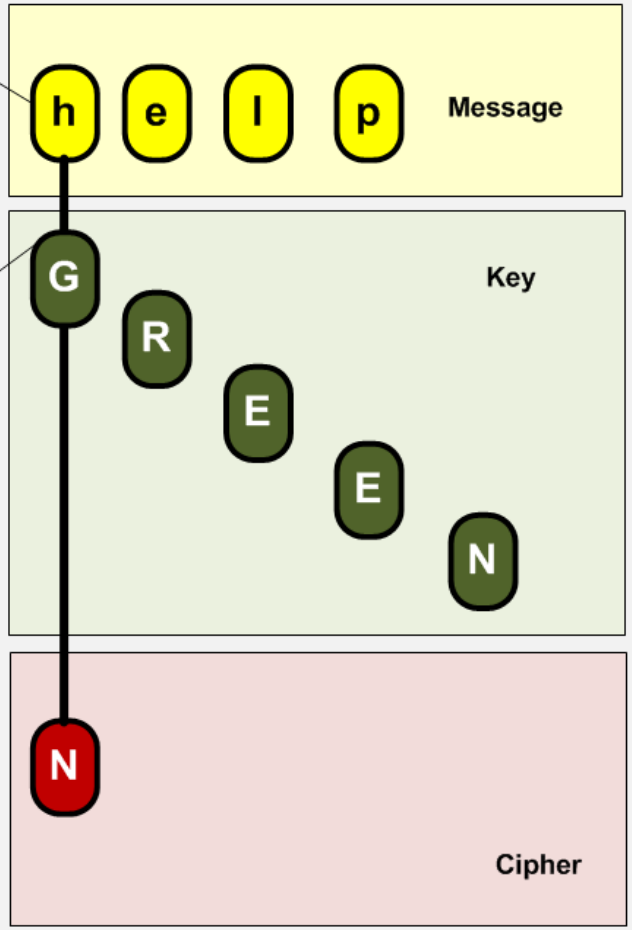
Mapping to normal

This table shows how the text matches a normal probability to text (where 'E' has the highest level of occurance and 'Z' has the least). The grey rows show what would be expected for the order, and the red one shows what your text gives for the order:

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

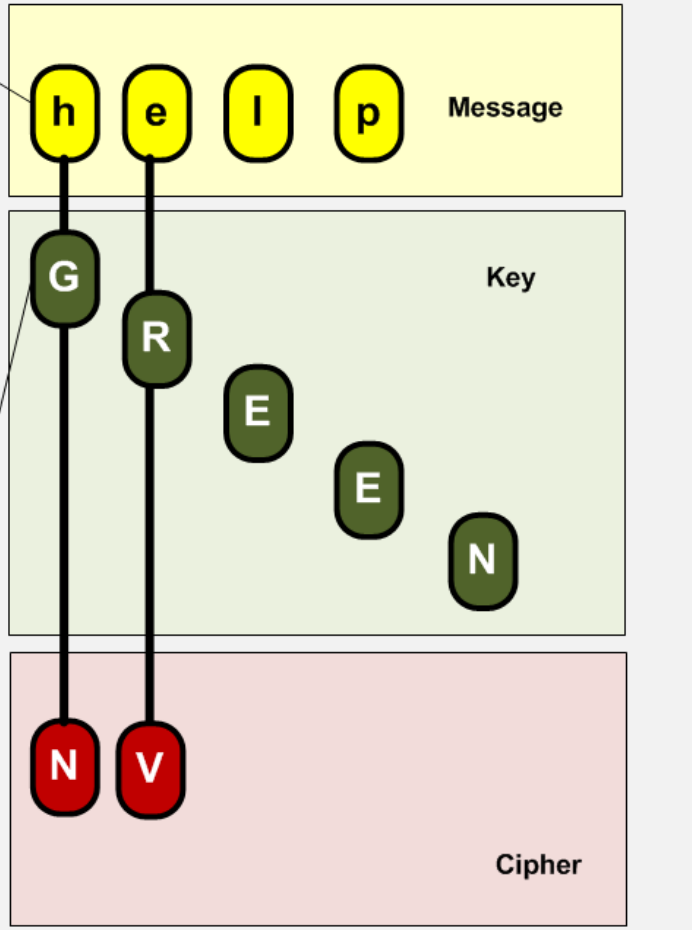
ONR ECRYAPFJ
RDUCIEORT JP
AO MGJ DPO AD
RDUCIEOAPD, LF
RDUCIEO GDT T
ADORCUNGDZR
GXAUR UGD ZRD
AJ XAJORDADZ
SRI RDUCIEOAP
ECPLXRK, GJ GX
ONGO LPL UGD
ONR PDXI SRI O
GXAUR'J ECAYG
NPXT PQQ). MR
ECPLXRKJ:- NPM
JRDO ONR TGO
GDT ONFJ ECRO
ONR KRJJGZR N
LPL TAJOCALFO
NGYADZ OP EPJ
XADR MNRD GX
CRGXXI OCFJO
MR UGD'O OCFJ
LPL. ONRJR WF
MR MAXX XPPS
TGOG, GDT ONR
GFONRDOAUGO
MGI ONGO G EF
TAZAOGX URCO
SRI. ONAJ UNGE
GFONRDOAUGO
UPDQATRDOAGXAOI (QAZFCR 4.1), GDT ONR FJGZR PQ
LAPKROCAUJ.

Z 0.09	RO 0.55	TED 0.44	OR 0.45



Vigenère cipher

- In 1553, invented by Giovan Battista Bellaso.
- In 1900s, attributed to Blaise de Vigenère.



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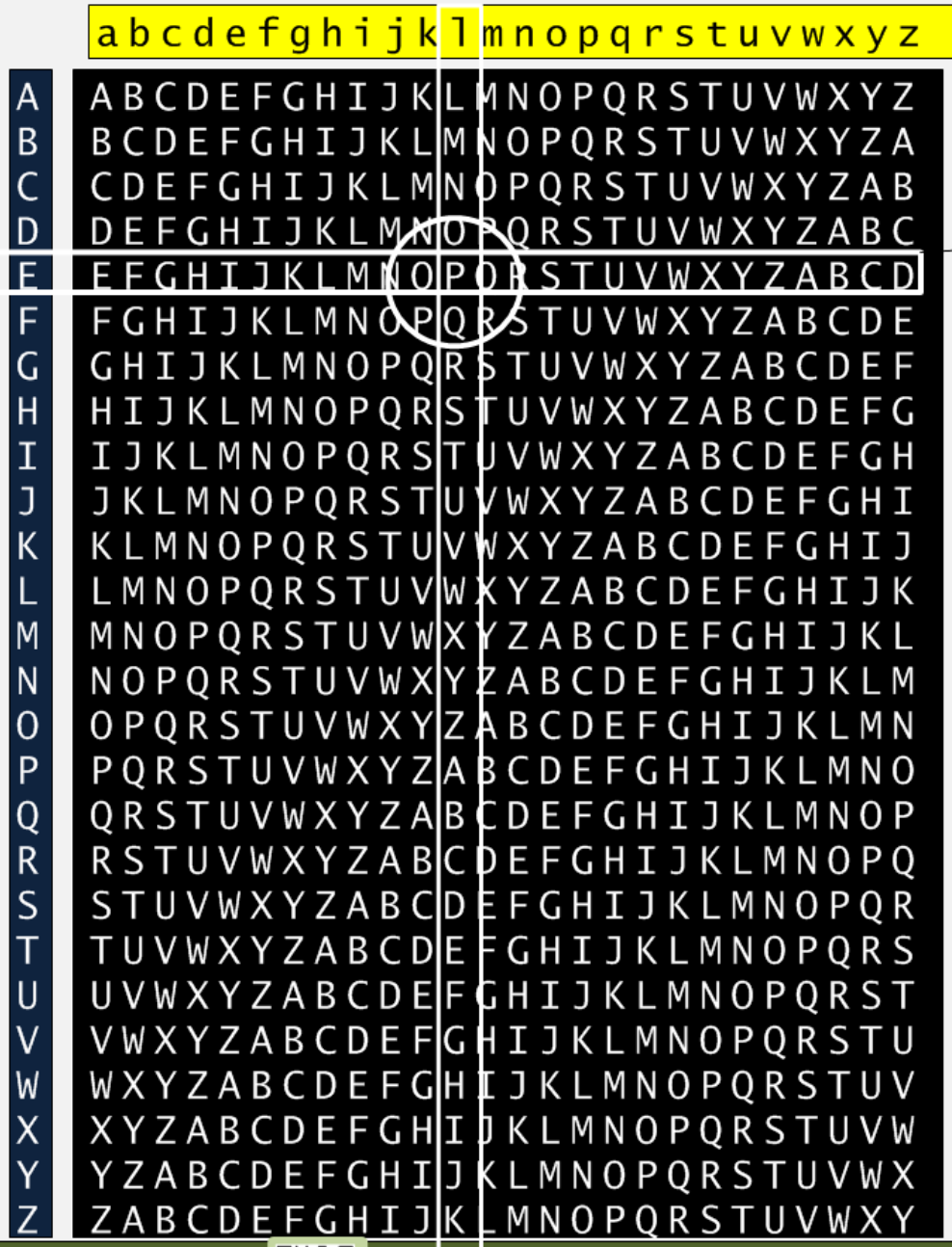

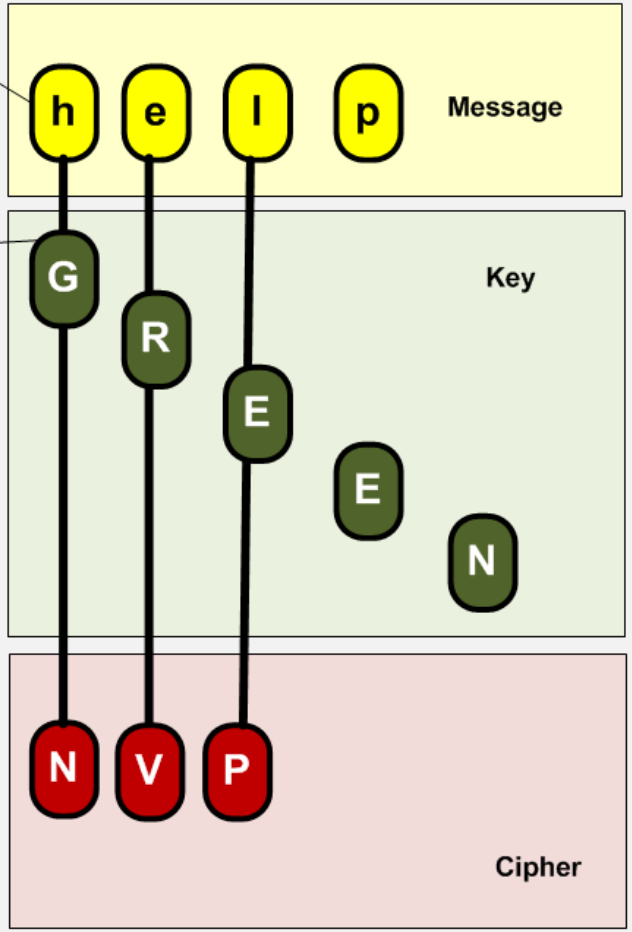

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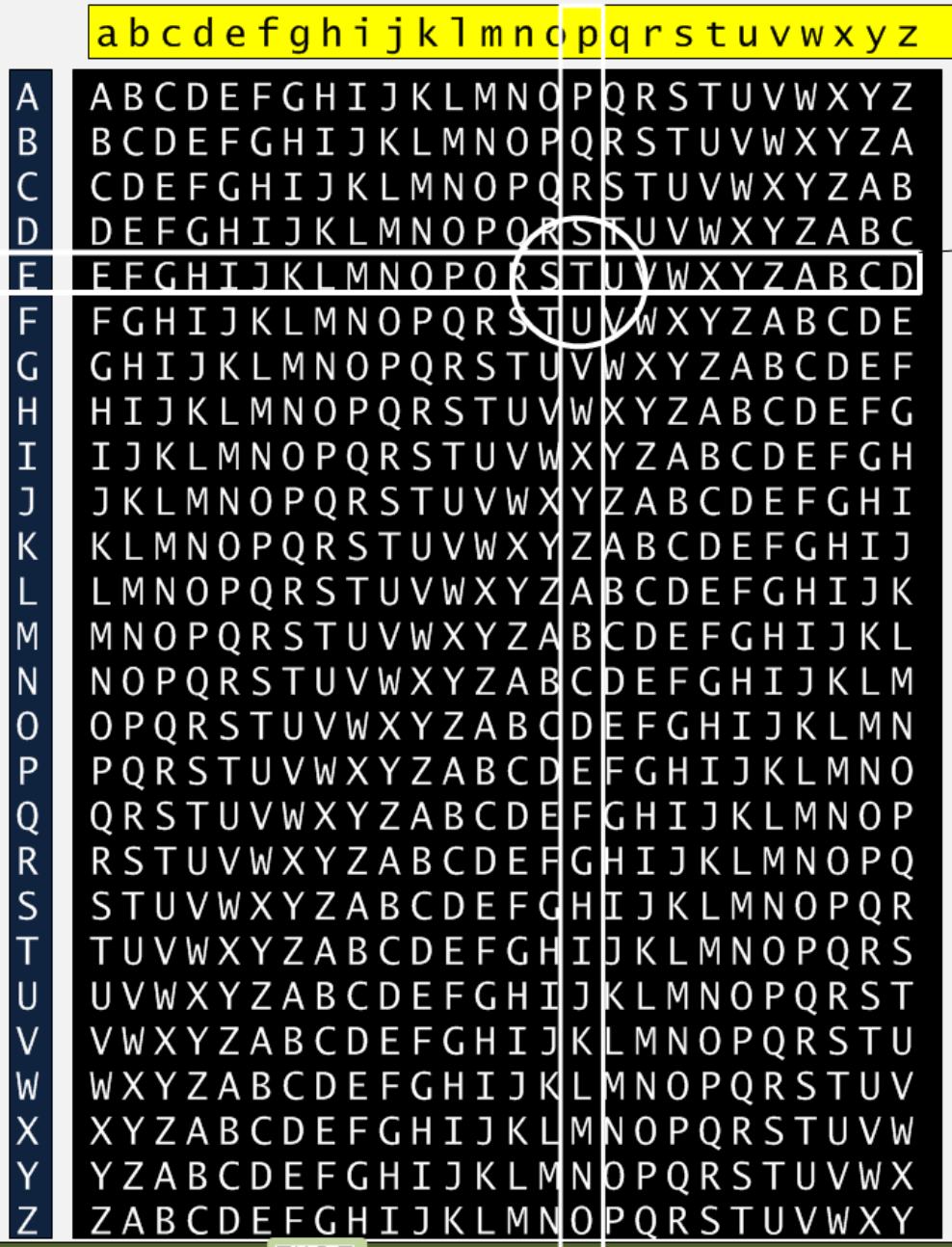

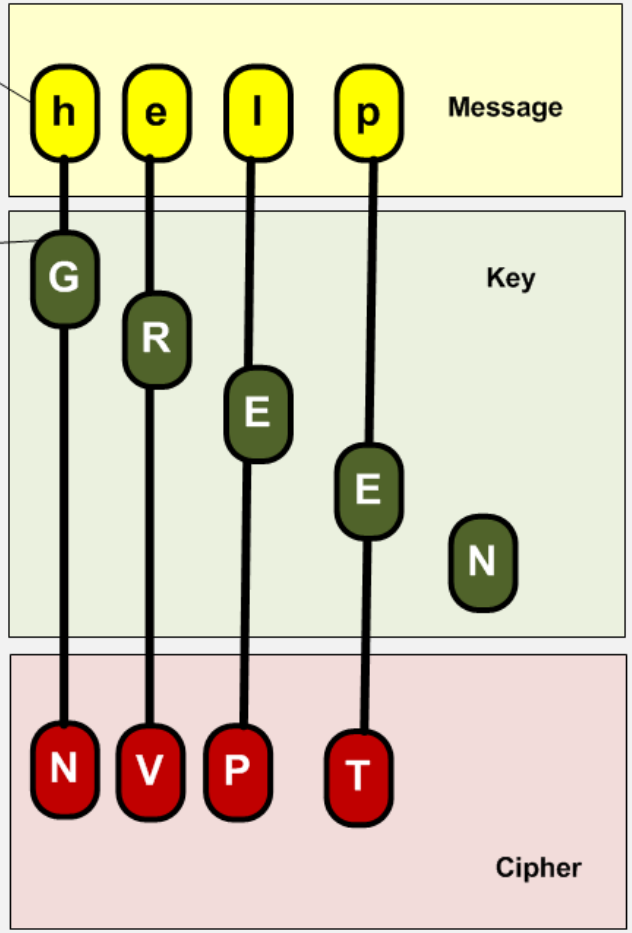

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Vigenère Calculator

[Back] This page defines a Vigenère Calculator:

Enter Word: help

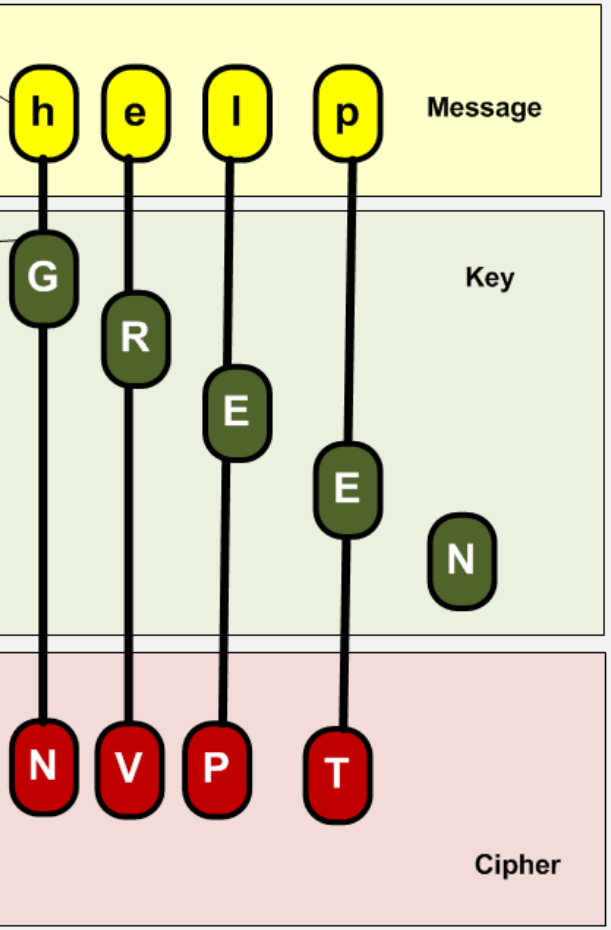
Enter Key: green

Analyse

Code: nvpt

Decode (just to check): help

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



Vigenère cipher

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Bob generates a random code book

gvlpj	iqqxe	wmrmn	bxwhi	mqmqt
zmuvz	cpmaq	rlvtn	kkfij	jowet
xqfuh	pjvvk	vwuyc	gaqvv	qbdty
bldgj	kqpcc	lkrtb	hpajr	opggd
jybjc	wnlwf	egplz	fgsvr	wjwun
batbj	m**e**xda	mogag	xyunw	baojm
hwloh	zbhvb	vtjns	ajmkn	qzrpt
xpjym	amkpb	ptiva	**k**hlzl	eo**hu**v
rodvv	iev**v**k	ksjja	jjuld	hbqkd
josep	iiocu	miout	kxmlq	rybzb

Bob sends Alice the code book

gvlpj	iqqxe	wmrmn	bxwhi	mqmqt
zmuvz	cpmaq	rlvtn	kkfij	jowet
xqfuh	pjvvk	vwuyc	gaqvv	qbdty
bldgj	kqpcc	lkrtb	hpajr	opggd
jybjc	wnlwf	egplz	fgsvr	wjwun
batbj	mexda	mogag	xyunw	baojm
hwloh	zbhvb	vtjns	ajmkn	qzrpt
xpjym	amkpb	ptiva	khlzl	eohuv
rodvv	ievvk	ksjja	jjuld	hbqkd
josep	iiocu	miout	kxmlq	rybzb

Bob uses a random sequence for his code:
[198][197][208][170][131][161][227][190]

To give: **uhvqetsk**

Bob sends Alice the key

Using Vigenère gives
Message: **shetland**
Key: **uhvqetsk**
Ciper: **mozjptfn**

Bob sends cipher:
mozjptfn

Using the pad, key and cipher, Alice can now decrypt:

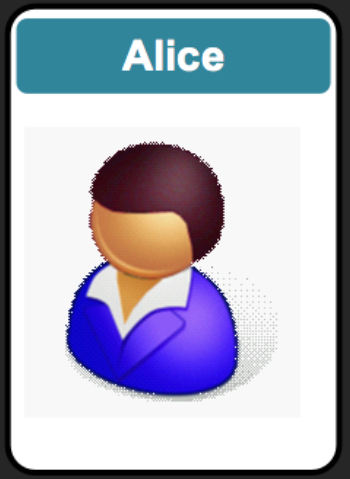
Message: **shetland**

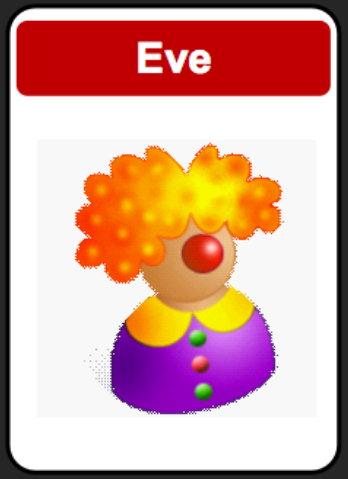
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z
07	11	17	10	25	08	44	19	02	18	41	42	40	00	16	01	15	04	06	05	13	22	45	12	55	47
31	64	33	27	26	09	83	20	03			81	52	43	30	62		24	34	23	14		46		93	
50		49	51	28			21	29			86		80	61			39	56	35	36					
63			76	32			54	53			95		88	65			58	57	37						
66				48			70	68					89	91			71	59	38						
77				67			87	73						94			00	90	60						
84				69										96					74						
				72															78						
				75															92						
				79																					
				82																					
				85																					

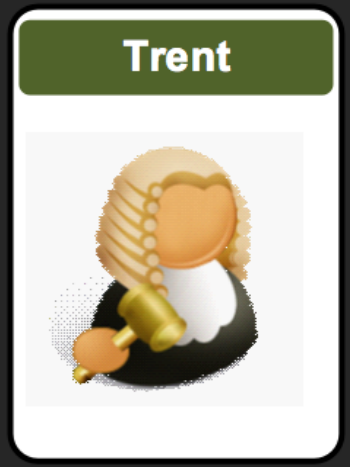
Plaintext	h	e	l	l	o	e	v	e	r	y	o	n	e
Ciphertext:	19	25	42	81	16	26	22	28	04	55	30	00	32

Advanced Crypto

1. Ciphers and Fundamentals



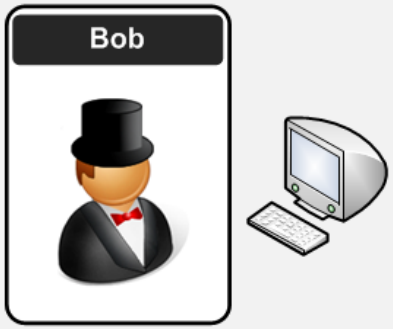




Encoding Methods

http://asecuritysite.com/crypto

Author: Prof Bill Buchanan



Binary values are difficult to view/edit, thus encrypted values are typically converted to hex or Base-64.

Hex

5e 20 e6 aa

Base-64

XiDmqg

'A' 'B' 'C' 'D'

ASCII characters

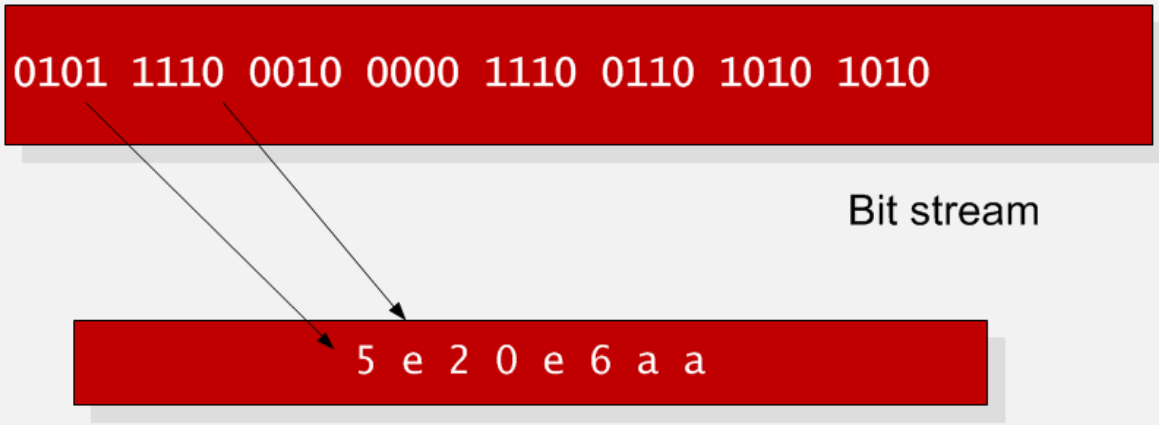
01000001 01000010
01000011 01000100

Byte values

Encryption

01011110 00100000
11100110 10101010

With hexadecimal, the bit stream is split into groups of four, and converted into hex values (0-9,A-F)



Decimal	Binary	Hex
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

With Base-64, the bits are split into groups of six, and then converted. Base-64 is used extensively on the Internet (such as in email).

Val	Enc	Val	Enc	Val	Enc	Val	Enc
0	A	16	Q	32	g	48	w
1	B	17	R	33	h	49	x
2	C	18	S	34	i	50	y
3	D	19	T	35	j	51	z
4	E	20	U	36	k	52	0
5	F	21	V	37	l	53	1
6	G	22	W	38	m	54	2
7	H	23	X	39	n	55	3
8	I	24	Y	40	o	56	4
9	J	25	Z	41	p	57	5
10	K	26	a	42	q	58	6
11	L	27	b	43	r	59	7
12	M	28	c	44	s	60	8
13	N	29	d	45	t	61	9
14	O	30	e	46	u	62	+
15	P	31	f	47	v	63	/

01100110 01110010 01100101 01100100

011001 100111 001001 100101 011001 00

Bit stream

Z n J l Z A = =

Base-64

The two main operators used in encryption are Ex-OR and ROR/ROL

The two main operators used in encryption are Ex-OR and ROL/ROR, as they are fast, and preserve info.

	1	1	0	0
+	1	0	0	1
	0	1	0	1

0	1	1	0	0	0	0	0

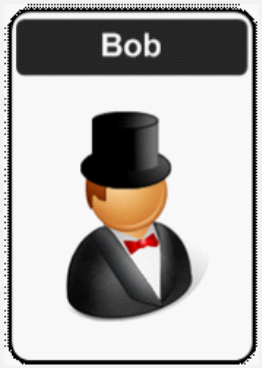
Rotate left (ROL) 2 bits

1	0	0	0	0	0	0	1

+ Exclusive-OR operation

Rotate left (ROL)

Rotate right (ROR)



The modulus is the remainder of a divide

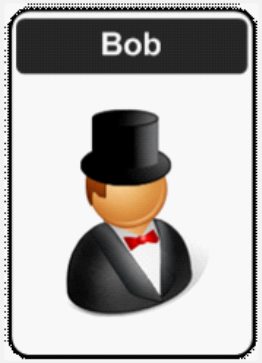
The Mod operator is used extensive in crytography

143 mod 5

28 rem 3

3

87 mod 9?



Non Printable:
New line (0x13)
Tab (0x07)
Backspace (0x08)

Printable:
Space (0x20)

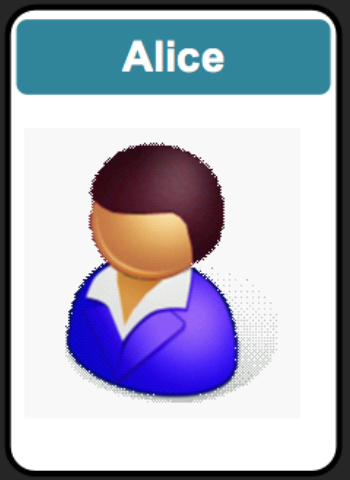
		UTF-16	ASCII		
A	65	0000000001000001	41	101	&#65;
B	66	0000000001000010	42	102	&#66;
C	67	0000000001000011	43	103	&#67;
D	68	0000000001000100	44	104	&#68;
E	69	0000000001000101	45	105	&#69;
F	70	0000000001000110	46	106	&#70;
G	71	0000000001000111	47	107	&#71;
H	72	0000000001001000	48	110	&#72;
I	73	0000000001001001	49	111	&#73;
J	74	0000000001001010	4a	112	&#74;
K	75	0000000001001011	4b	113	&#75;
L	76	0000000001001100	4c	114	&#76;
M	77	0000000001001101	4d	115	&#77;

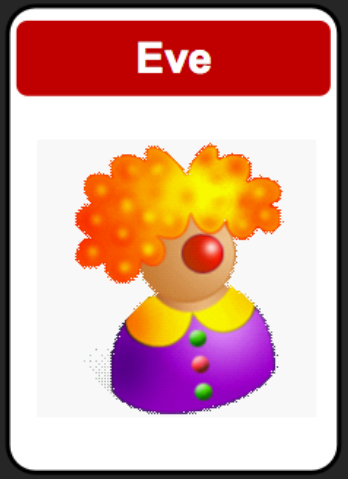
Decimal | Hex | Oct | HTML

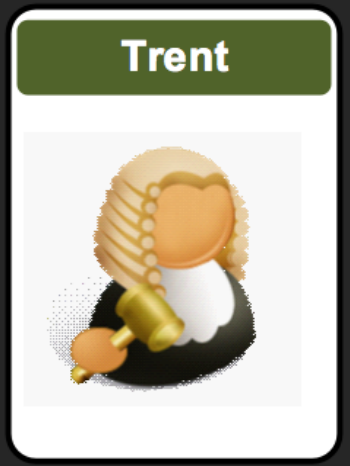
Advanced Crypto

1. Ciphers and Fundamentals

Prime Numbers, Large Numbers and GCD

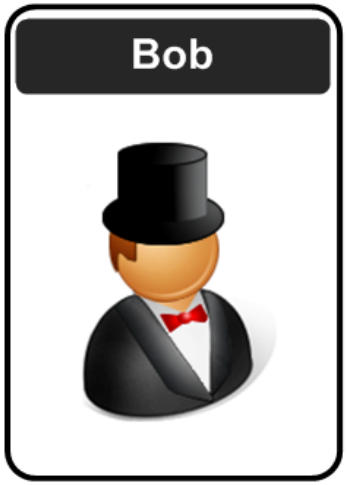


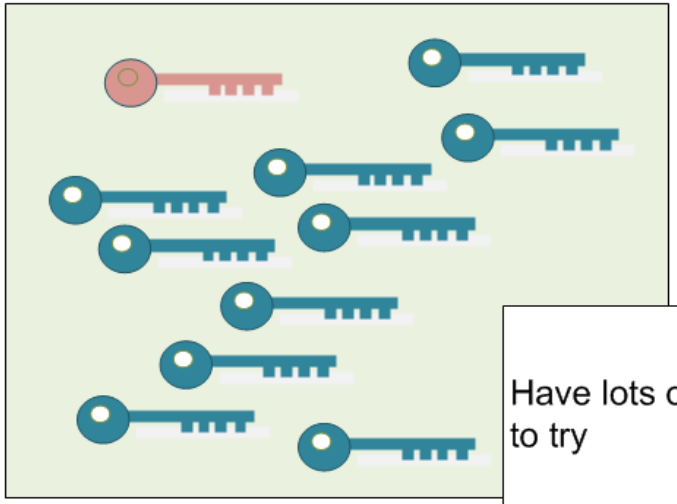




http://asecuritysite.com/crypto

Author: Prof Bill Buchanan





Have lots of different things to try

13,407,807,929,942,597,099,574,024,998,205,846,127,479,365,820,592,393,377,723,561,443,721,764,030,073,546,976,801,874,298,166,903,427,690,031,858,186,486,050,853,753,882,811,946,569,946,433,649,006,084,096

Make it mathematically difficult … prime numbers … and large number maths

Prime numbers are difficult to factorize

2,3,5,7,11,13,
17,19,23,29,31,37,...

p

1231

q

9551

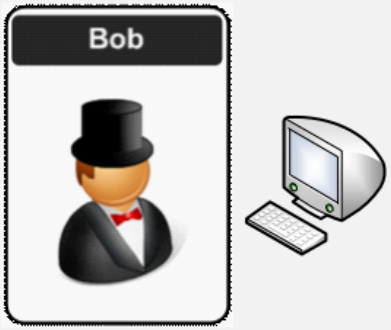
p-1

q-1

11,746,500

(p-1)(q-1)

Primes of 12?



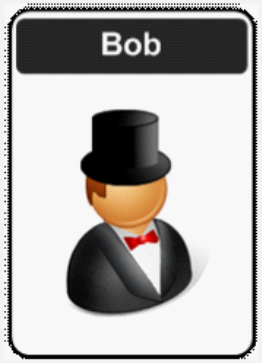
In cryptography we often find the Greatest Common Denominator (GCD)

42,56

Factors: 2 14

GCD

GCD of 12,30?



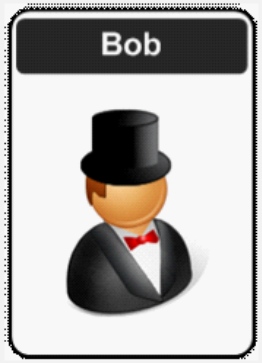
32,317,006,071,311,007,300,714,876,688,669,951,960,444,102,669,715,484,032,130,345,427,524,655,138,867,890,893,197,201,411,522,913,463,688,717,960,921,898,019,494,119,559,150,490,921,095,088,152,386,448,283,120,630,877,367,300,996,091,750,197,750,389,652,106,796,057,638,384,067,568,276,792,218,642,619,756,161,838,094,338,476,170,470,581,645,852,036,305,042,887,575,891,541,065,808,607,552,399,123,930,385,521,914,333,389,668,342,420,684,974,786,564,569,494,856,176,035,326,322,058,077,805,659,331,026,192,708,460,314,150,258,592,864,177,116,725,943,603,718,461,857,357,598,351,152,301,645,904,403,697,613,233,287,231,227,125,684,710,820,209,725,157,101,726,931,323,469,678,542,580,656,697,935,045,997,268,352,998,638,215,525,166,389,437,335,543,602,135,433,229,604,645,318,478,604,952,148,193,555,853,611,059,596,230,656

2,048 bit integer

Cryptography uses Big Integers … 512 bits, 1,024 bits, 2,048 bits ...

Typical sizes of integers

Bits	Max value
16	**65,536**
32	**4,294,967,296**
48	281,474,976,710,656
64	**18,446,744,073,709,551,616**
80	1,208,925,819,614,629,174,706,176
96	79,228,162,514,264,337,593,543,950,336
112	5,192,296,858,534,827,628,530,496,329,220,096
128	340,282,366,920,938,463,463,374,607,431,768,211,456
144	22,300,745,198,530,623,141,535,718,272,648,361,505,980,416
160	1,461,501,637,330,902,918,203,684,832,716,283,019,655,932,542,97 6
176	95,780,971,304,118,053,647,396,689,196,894,323,976,171,195,136,4 75,136
192	6,277,101,735,386,680,763,835,789,423,207,666,416,102,355,444,46 4,034,512,896
208	411,376,139,330,301,510,538,742,295,639,337,626,245,683,966,408, 394,965,837,152,256
224	26,959,946,667,150,639,794,667,015,087,019,630,673,637,144,422,5 40,572,481,103,610,249,216
240	1,766,847,064,778,384,329,583,297,500,742,918,515,827,483,896,87 5,618,958,121,606,201,292,619,776



Lotteries and Draws	TRNG
Games and Gambling	TRNG
Random Sampling	TRNG
Simulation and Modelling	PRNG
Security	TRNG

Pseudo-Random Number Generators (PRNGs). Repeat after a given time. Fast. Deterministic. Periodic.

True Random Number Generators (TRNGs). True random eg keystroke analysis. Slow. Non-deterministic. Aperiodic.

192-bit random:

8aa209c1432e25840857fbe82675299083009a327332181
63f2787cf8e50a1d3d8388b4864b36d70ae52304412788aa
7799a53155755e06b3d7afc8118f2bbde1993f07ef169f1c
...

128-bit random:
YSITF-RKRTC-KZUBW-FBQLF-YZZHL-VTQAQ-QTTWI-AUGYI-FVTEP-LKDAZ-APIVE-PSCZZ
WQMZH-VRYLS-IUJAE-AQWJT-AWJPY-KCVMH-AUVPY-OFDNC-DNPGY-EAQCA-GRFKK-FYLSF

Bob

CRC-32 Example

[Back] CRC is one of the most reliable error detection schemes and can detect up to 95.5% of all errors. The most commonly used code is the CRC-32 standard code which is defined by the CCITT, and will give a 32-bit CRC signature (8 hex characters). This signature is normally appended onto the data, and then checked when the data is read. If the CRC-32 check differs from the stored value, there is likely to be an error in the data. [Theory][Background]

The basic idea of a CRC can be illustrated using an example. Suppose the transmitter and receiver were both to agree that the numerical value sent by the transmitter would always be divisible by 9. Then should the receiver get a value which was not divisible by 9 would know it knows that there had been an error. For example, if a value of 32 were to be transmitted it could be changed to 320 so that the transmitter would be able to add to the least significant digit, making it divisible by 9. In this case the transmitter would add 4, making 324. If this transmitted value were to be corrupted in transmission then there would only be a 10% chance that an error would not be detected.

Message:

```
The quick brown fox jumps over the lazy dog
```

The quick brown fox jumps over the lazy dog

Generate CRC-32

The results are then:

CRC-32

```
414fa339
```

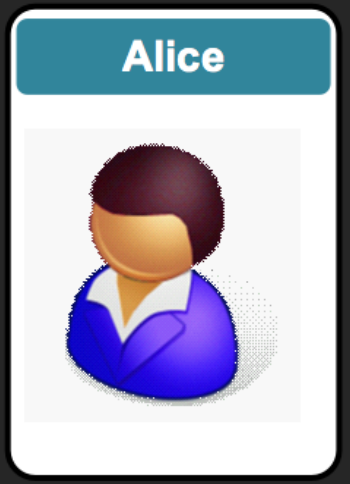
414fa339

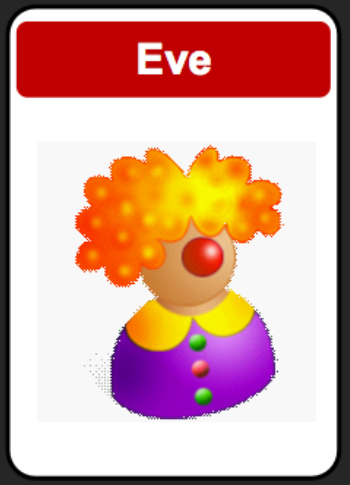
Examples

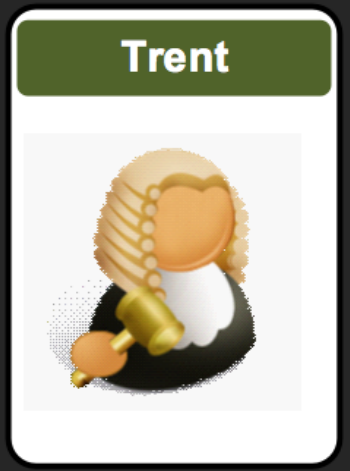
- Try "The quick brown fox jumps over the lazy dog". Try!, which should give a CRC-32 value of: 414fa339 Check
- Try "Test vector from febooti.com". Try!, which should give a CRC-32 value of: 0c877f61 Check
- Try "". Try!, which should give a CRC 32 value of 00000000 Check

Advanced Crypto

1. Ciphers and Fundamentals



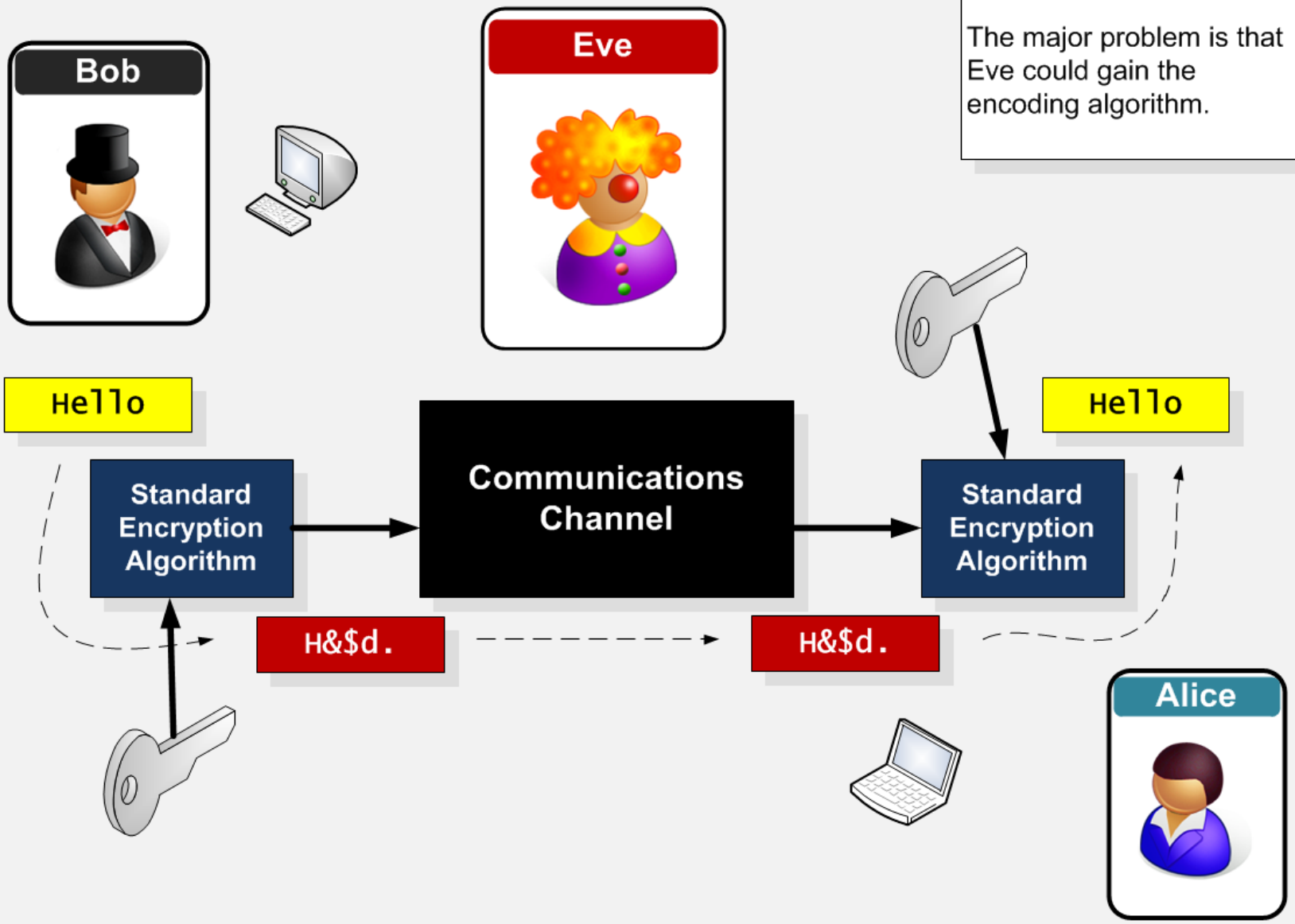


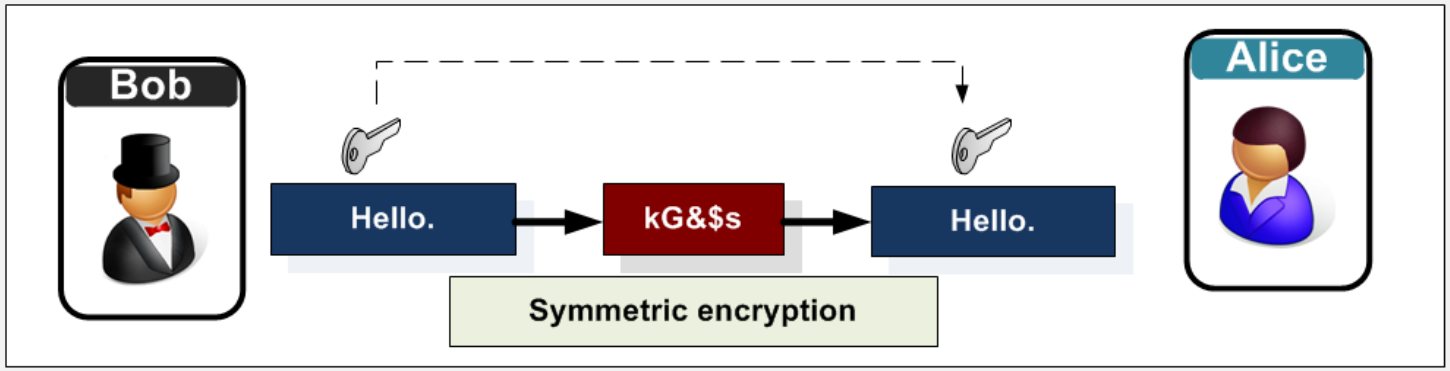


Key-based Encryption

http://asecuritysite.com/crypto

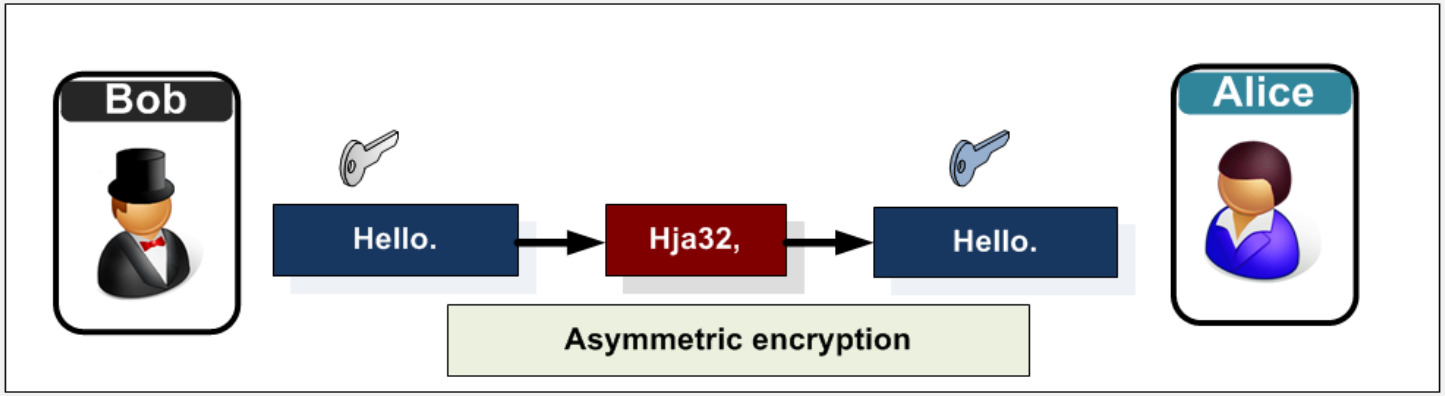
Author: Prof Bill Buchanan


Bob
Eve
The major problem is that Eve could gain the encoding algorithm.
Hello
Standard Encryption Algorithm
Communications Channel
Standard Encryption Algorithm
Hello
H&$d.
H&$d.
Alice



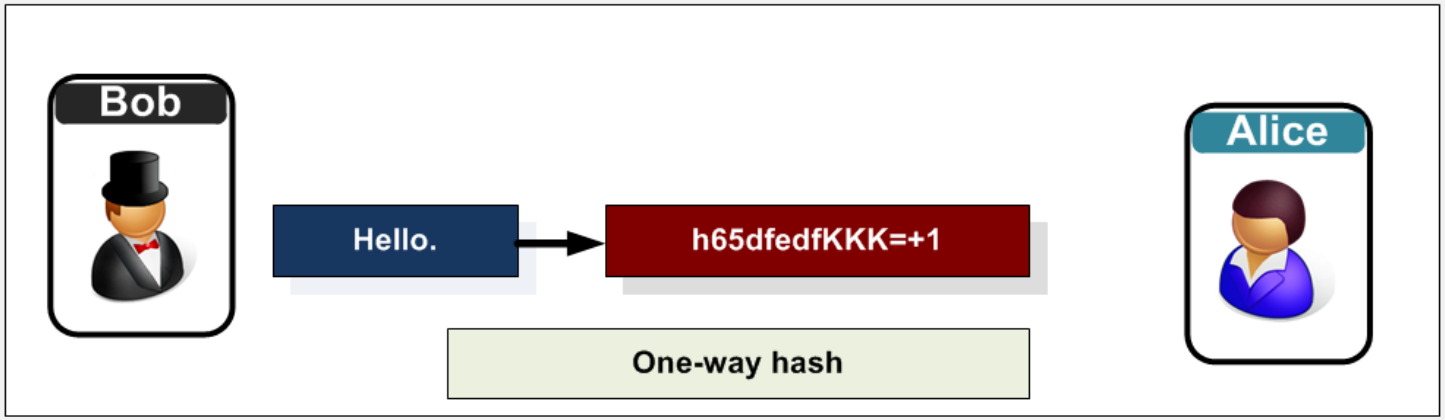
Private-key

Private-key: RC2, RC4, DES, 3DES, AES



Public-key

Public-key: RSA, DSA (factoring prime numbers) FIPS 186-2, ElGamal (Elliptic curve)



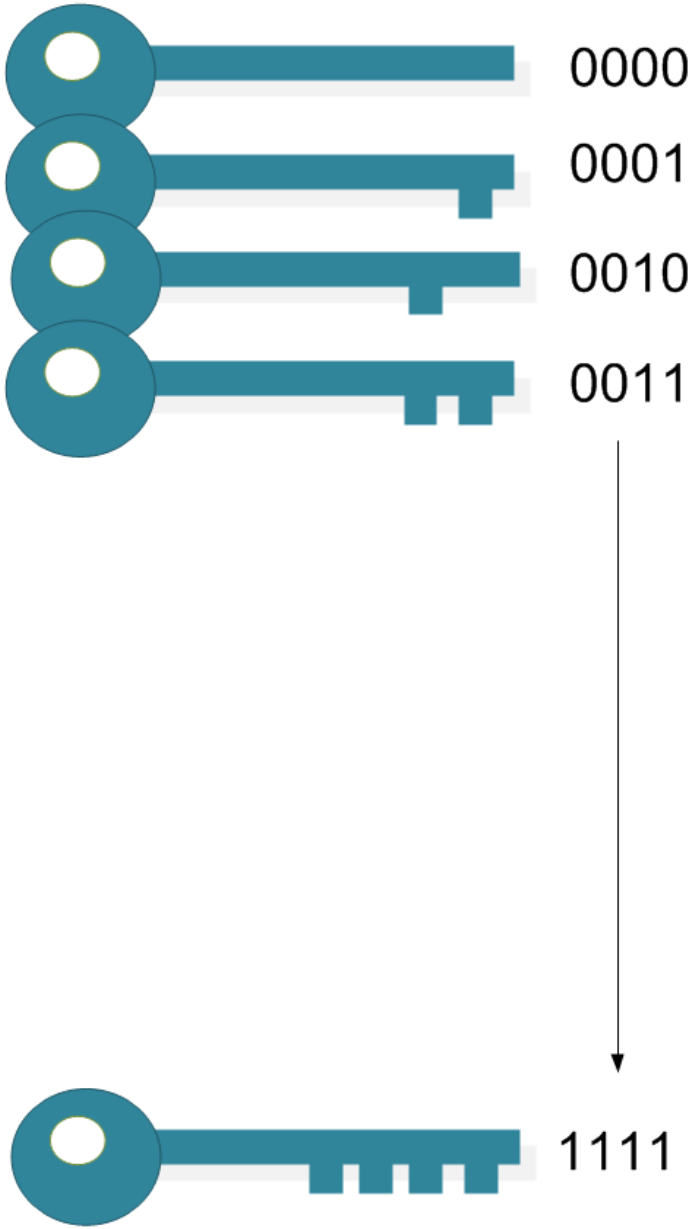
Hashing

Hashing: MD5, SHA-1

Strength: 80-bit DES -> 1024 RSA -> 160 bit Elliptic

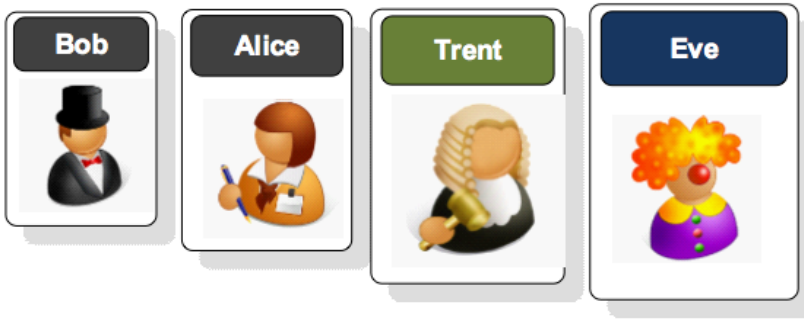
How safe is the key?
- the more keys … the less likely it is to find the key.

For example, if we have a key with four notches … each which can exist or not … how many keys can we have?



16 key combinations

2 to the power of 4 (2^4)



Number of keys

The larger the key, the greater the key space.

Code size	Number of keys	Code size	Number of keys	Code size	Number of keys
1	2	12	4,096	52	4.5×10^{15}
2	4	16	65,536	56	7.21×10^{16}
3	8	20	1,048,576	60	1.15×10^{18}
4	16	24	16,777,216	64	1.84×10^{19}
5	32	28	2.68×10^{8}	68	2.95×10^{20}
6	64	32	4.29×10^{9}	72	4.72×10^{21}
7	128	36	6.87×10^{10}	76	7.56×10^{22}
8	256	40	1.1×10^{12}	80	1.21×10^{24}
9	512	44	1.76×10^{13}	84	1.93×10^{25}
10	1024	48	2.81×10^{14}	88	3.09×10^{26}

Cryptography Fundamentals

Traditional ciphers.
Frequency Analysis.
Operators and GCD.
Encoding.
Big Integers.
Random Numbers.
Key-based Encryption.

Prof Bill Buchanan OBE

http://asecuritysite.com/encryption

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