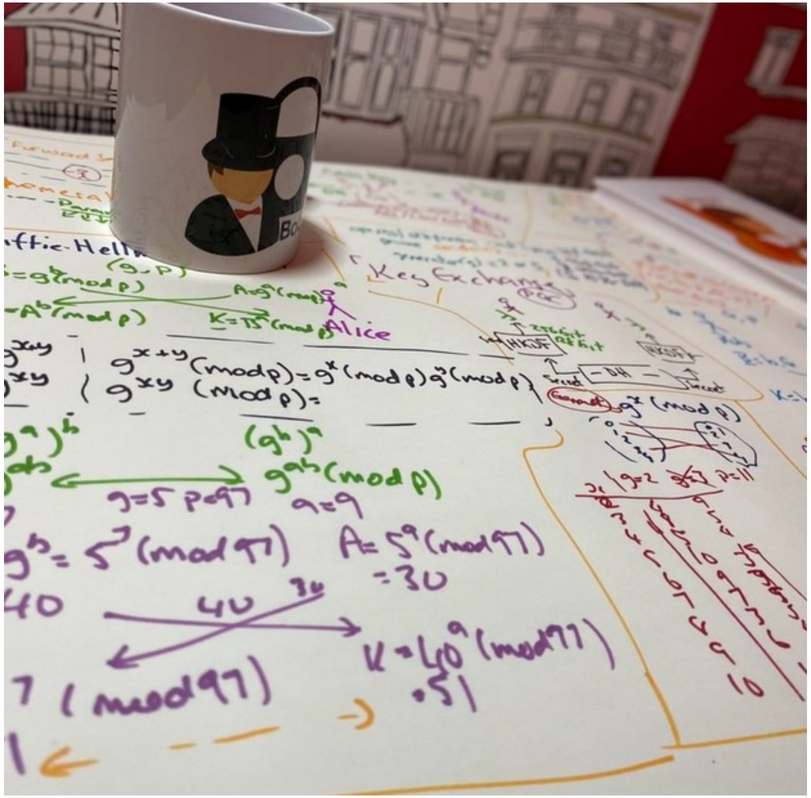
Key Exchange

Diffie-Hellman
Diffie-Hellman Weaknesses
Passing Key Using Public Key



Prof Bill Buchanan OBE

http://asecuritysite.com/crypto05
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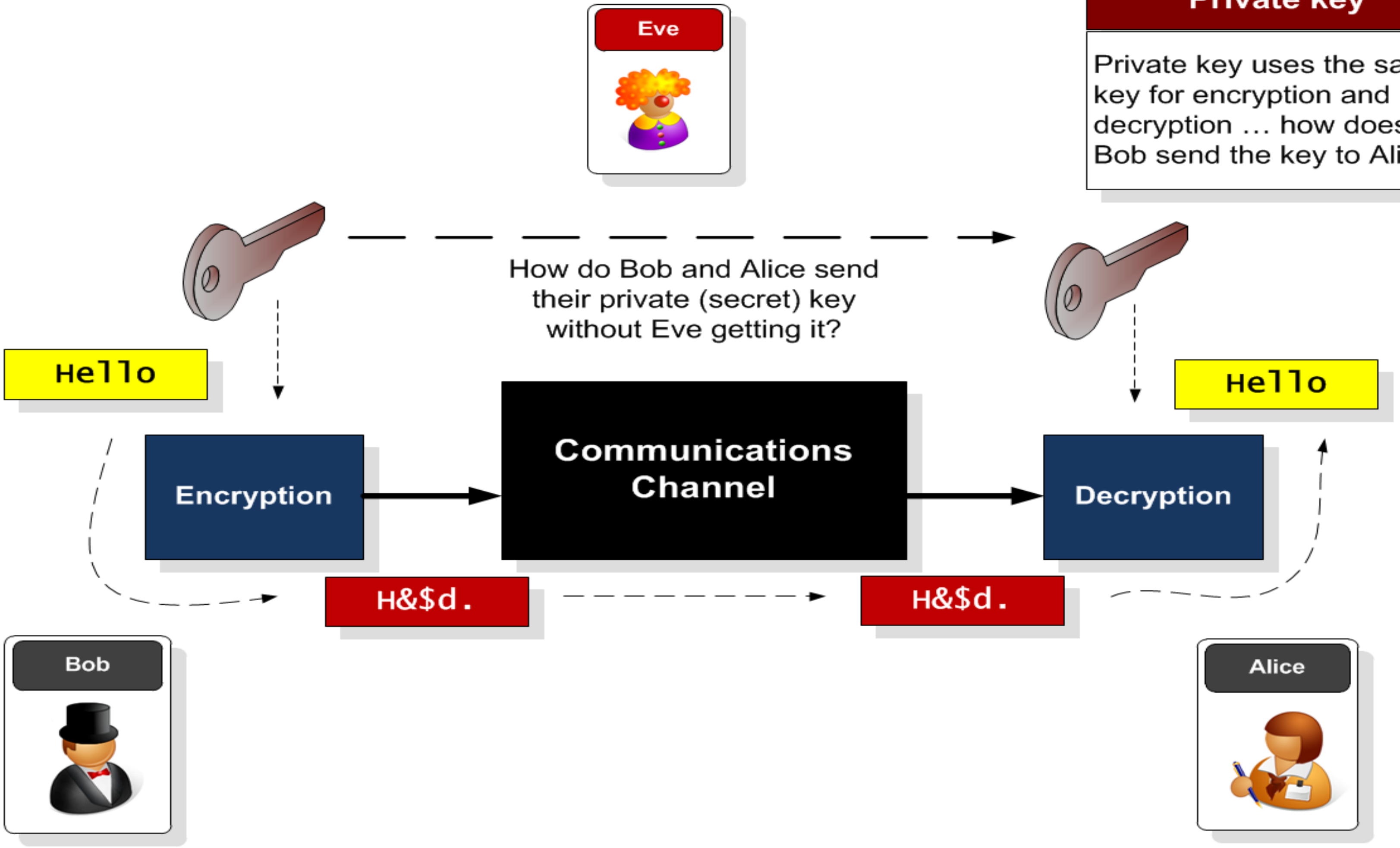
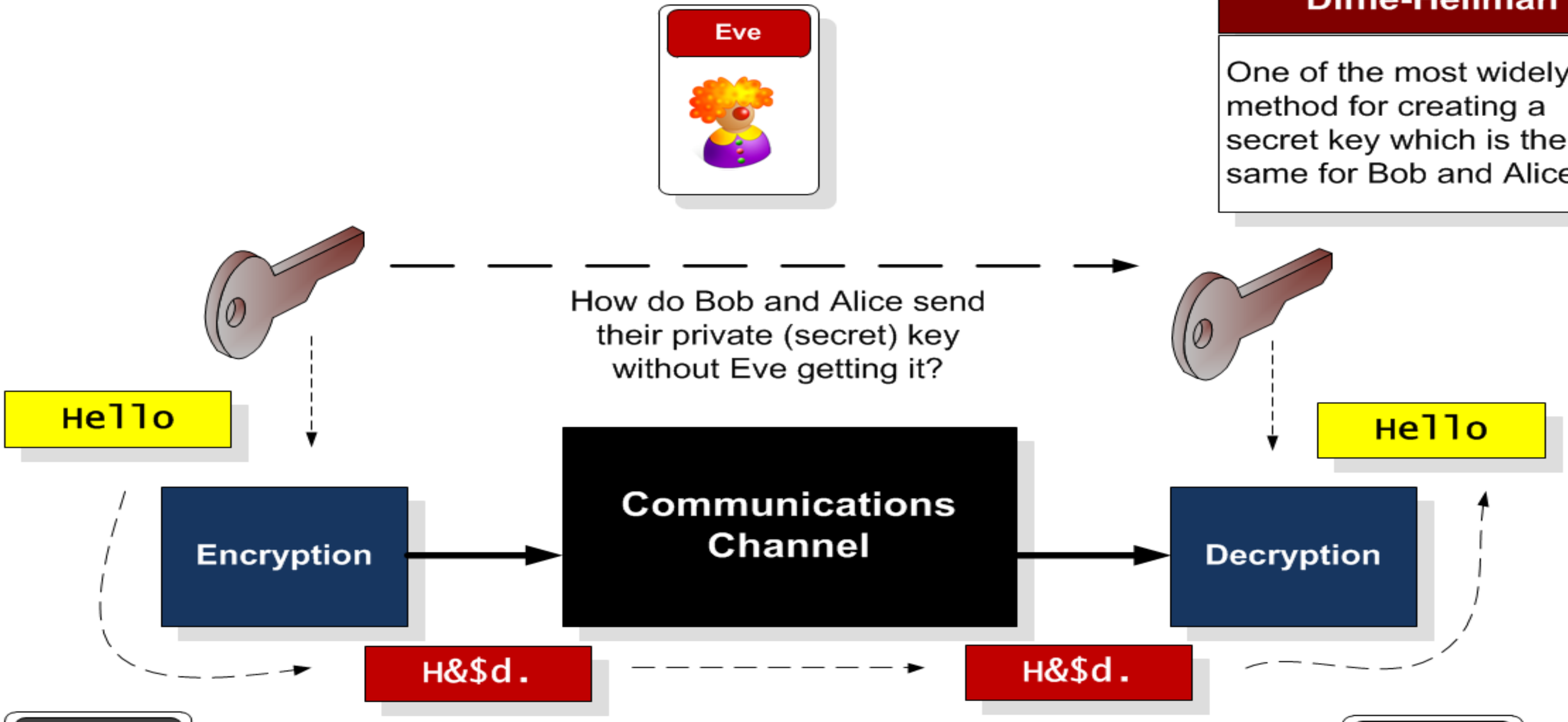
Private key

Private key uses the same key for encryption and decryption … how does Bob send the key to Alice?

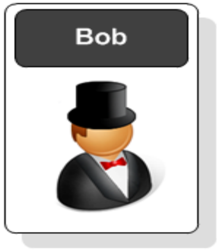

Eve
How do Bob and Alice send their private (secret) key without Eve getting it?
Hello
Encryption
Communications Channel
Decryption
Hello
H&$d.
H&$d.
Bob
Alice

Diffie-Hellman

One of the most widely method for creating a secret key which is the same for Bob and Alice



How do Bob and Alice send their private (secret) key without Eve getting it?



This problem was solved by Whitfield Diffie, who created the Diffie-Hellman algorithm, which is the most widely used method for passing secret keys

Key Exchange

- **Forward secrecy** (FS), which means that a comprise of the long-term keys will not compromise any previous session keys. A leakage of the public key of the server would cause all the sessions which used this specific public key to be compromised. FS thus aims to overcome this by making sure that all the sessions keys could not be compromised, even though the long-term key was compromised.
- **Ephemeral**. With some key exchange methods, the same key will be generated if the same parameters are used on either side. This can cause problems as an intruder could guess the key, or even where the key was static and never changed. With ephemeral methods, a different key is used for each connection, and, again, the leakage of any long-term would not cause all the associated session keys to be breached.

Eve

Bob

Alice

A^xA^y → $A^{(x+y)}$

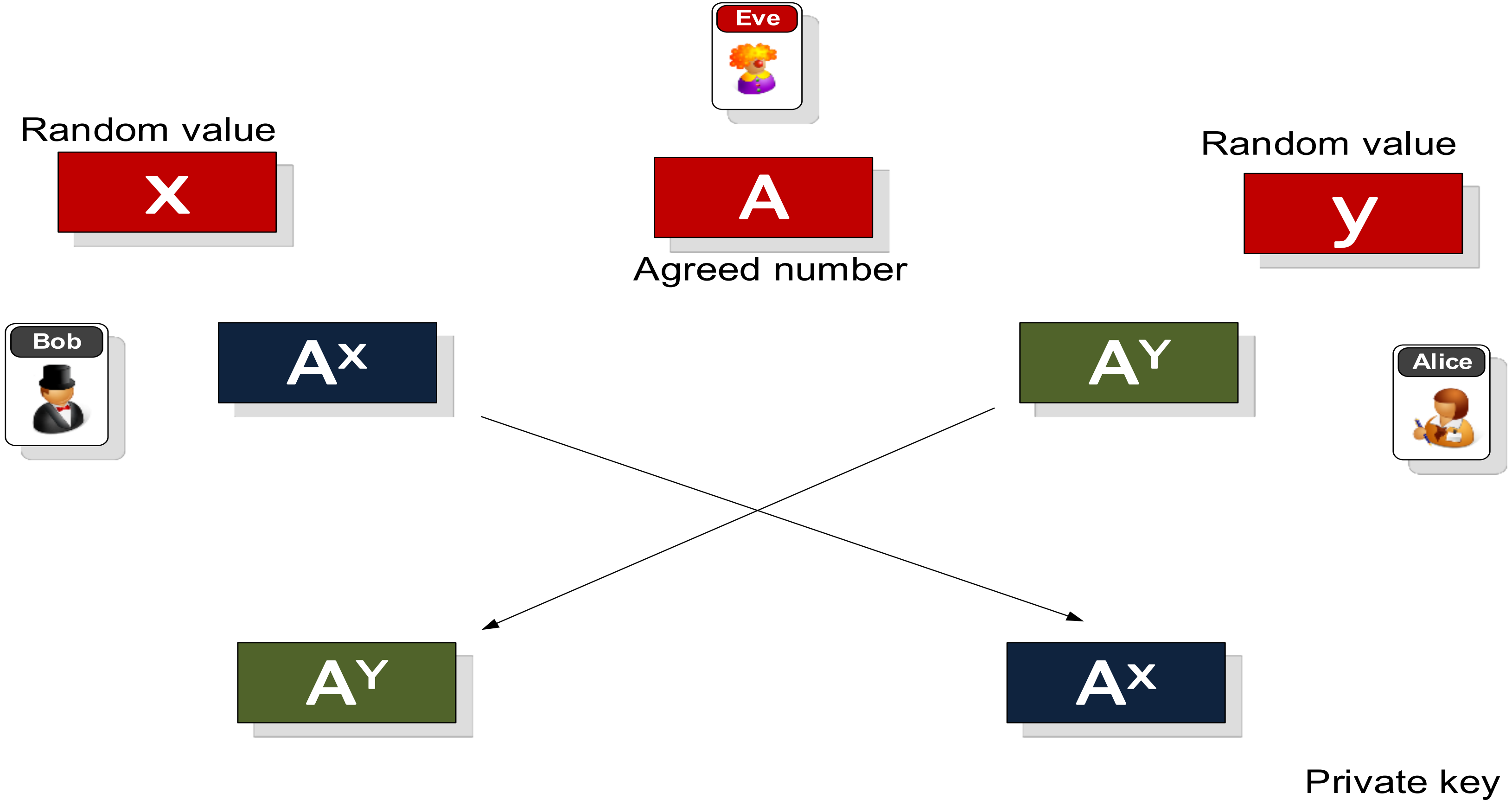
$(A^x)^y$ → A^{xy}

John

Logs

Encryption

Author: Prof Bill Buchanan



Eve

Random value

x

A

Agreed number

Random value

y

Bob

A^x

A^Y

Alice

A^Y

A^x

Private key

Logs

Encryption

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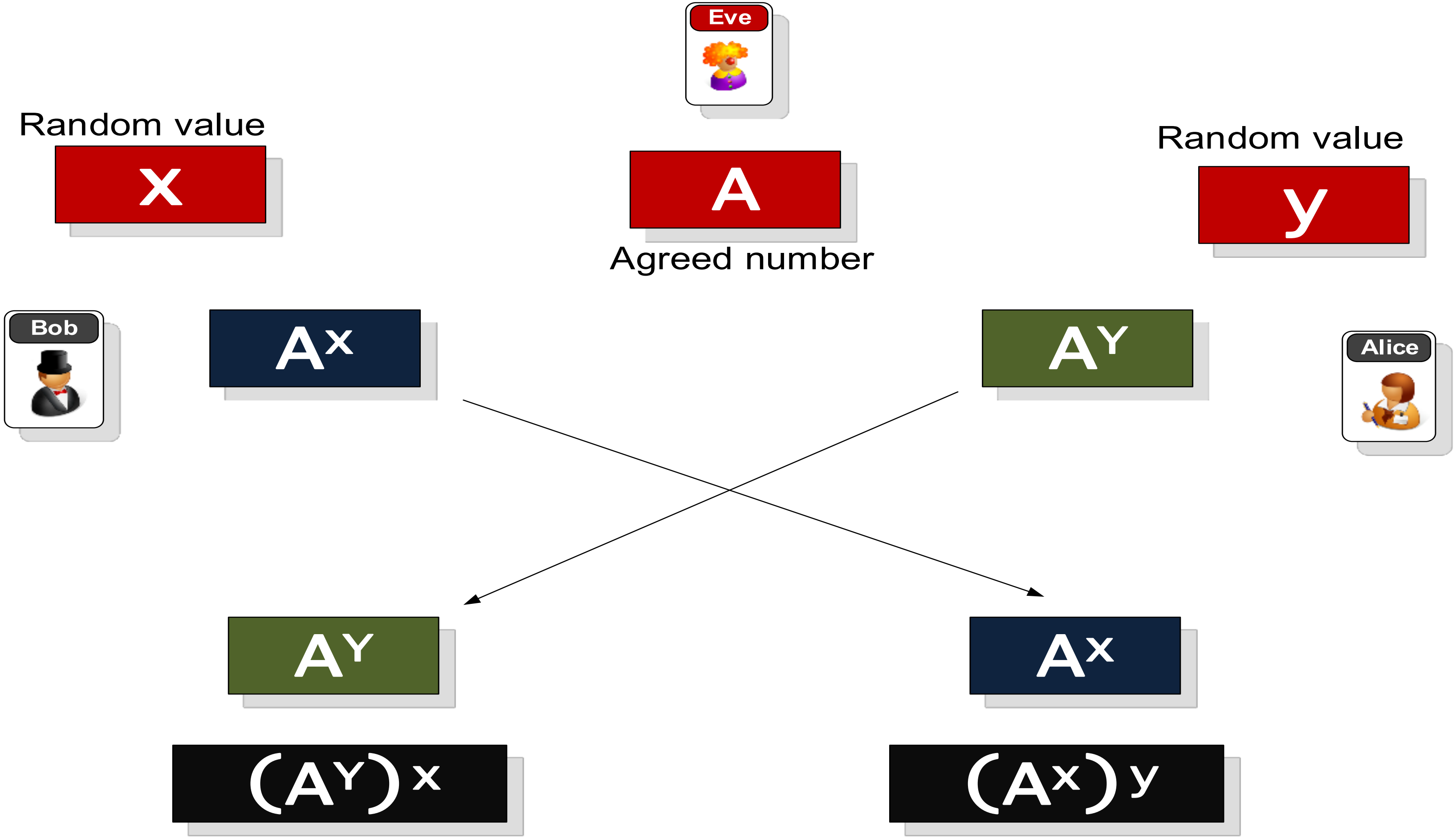


Eve

Random value

x

A

Agreed number

Random value

y

Bob

A^x

A^Y

Alice

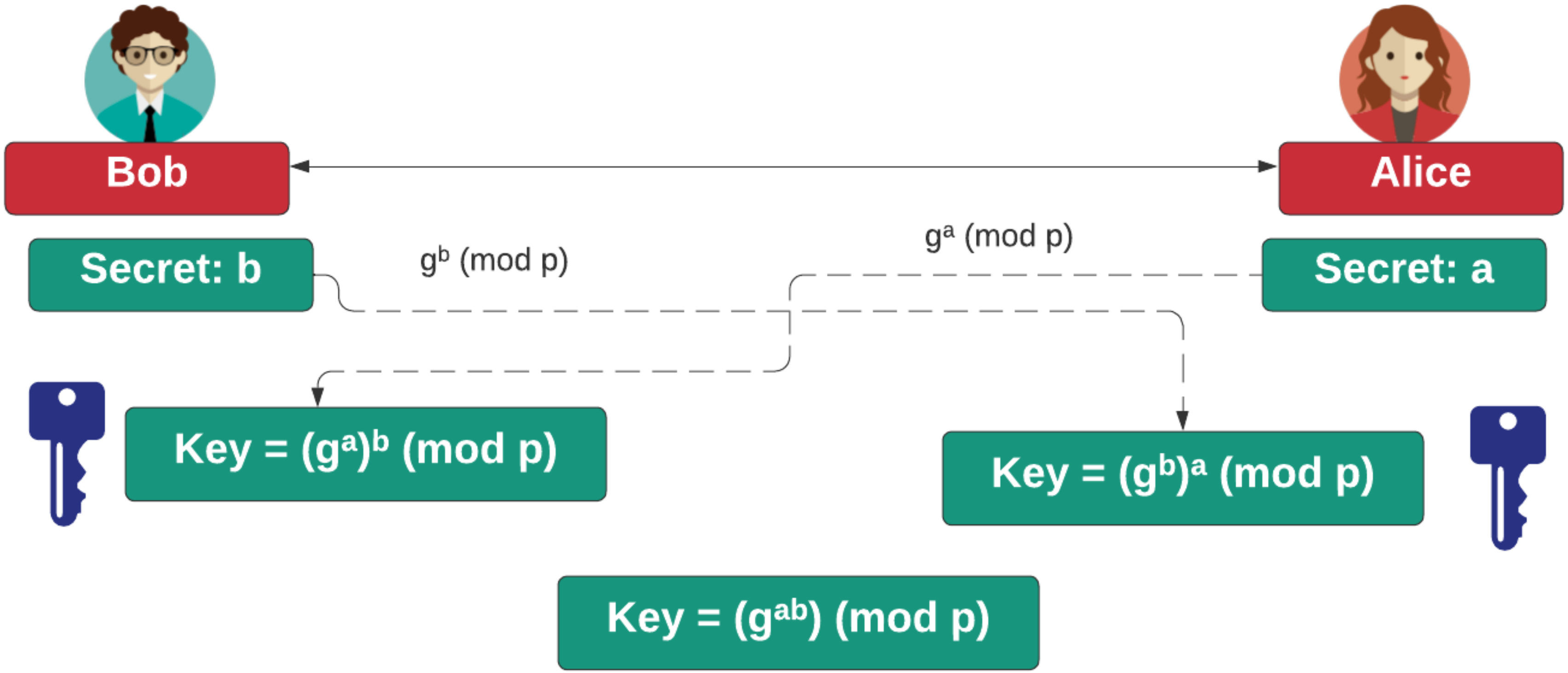
A^Y

A^x

$(A^Y)^x$

$(A^x)^y$

Author: Prof Bill Buchanan



Bob

Alice

Secret: b

g^b (mod p)

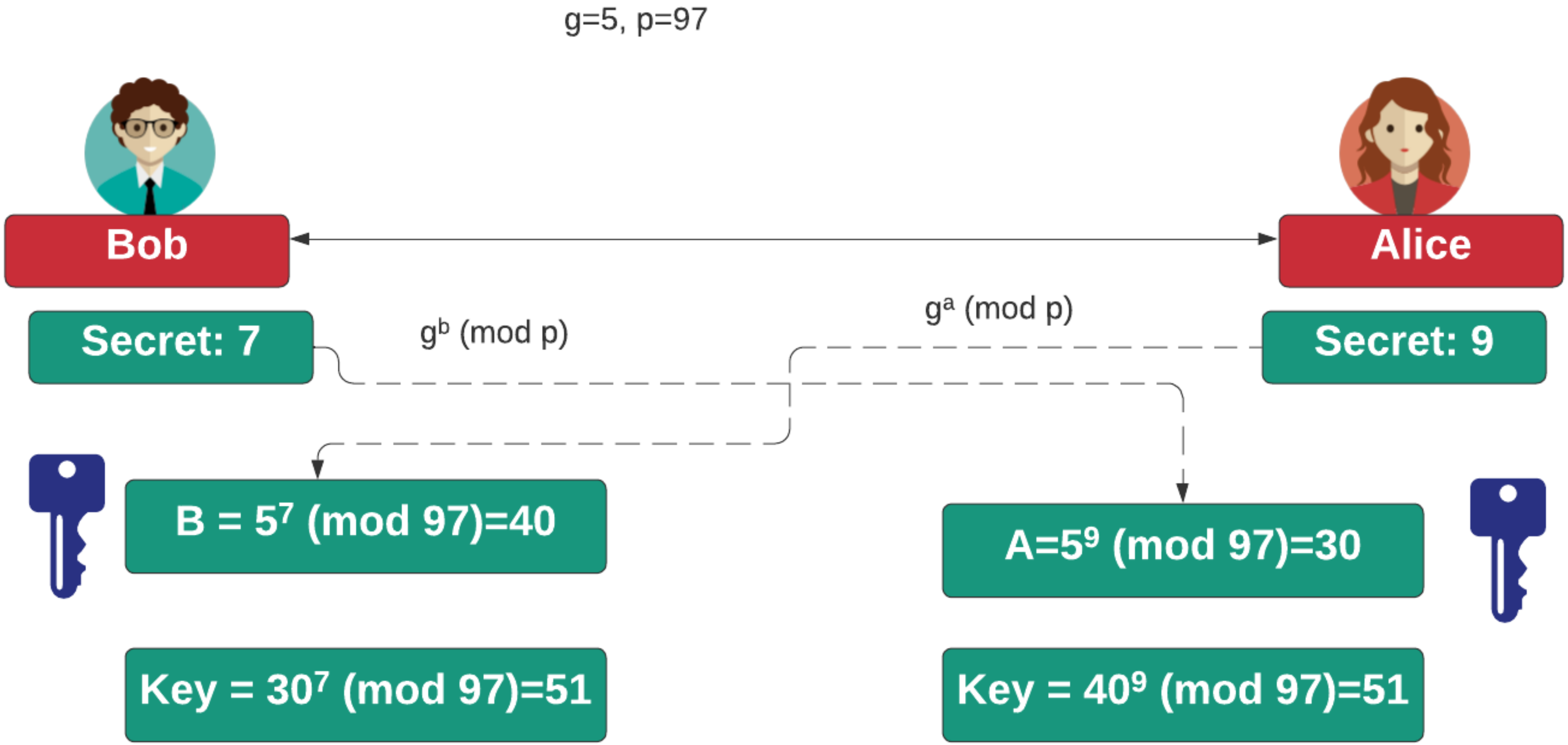
g^a (mod p)

Secret: a

Key = $(g^a)^b$ (mod p)

Key = $(g^b)^a$ (mod p)

Key = (g^{ab}) (mod p)



$g=5$, $p=97$

Bob

Alice

Secret: 7

Secret: 9

$g^b \pmod p$

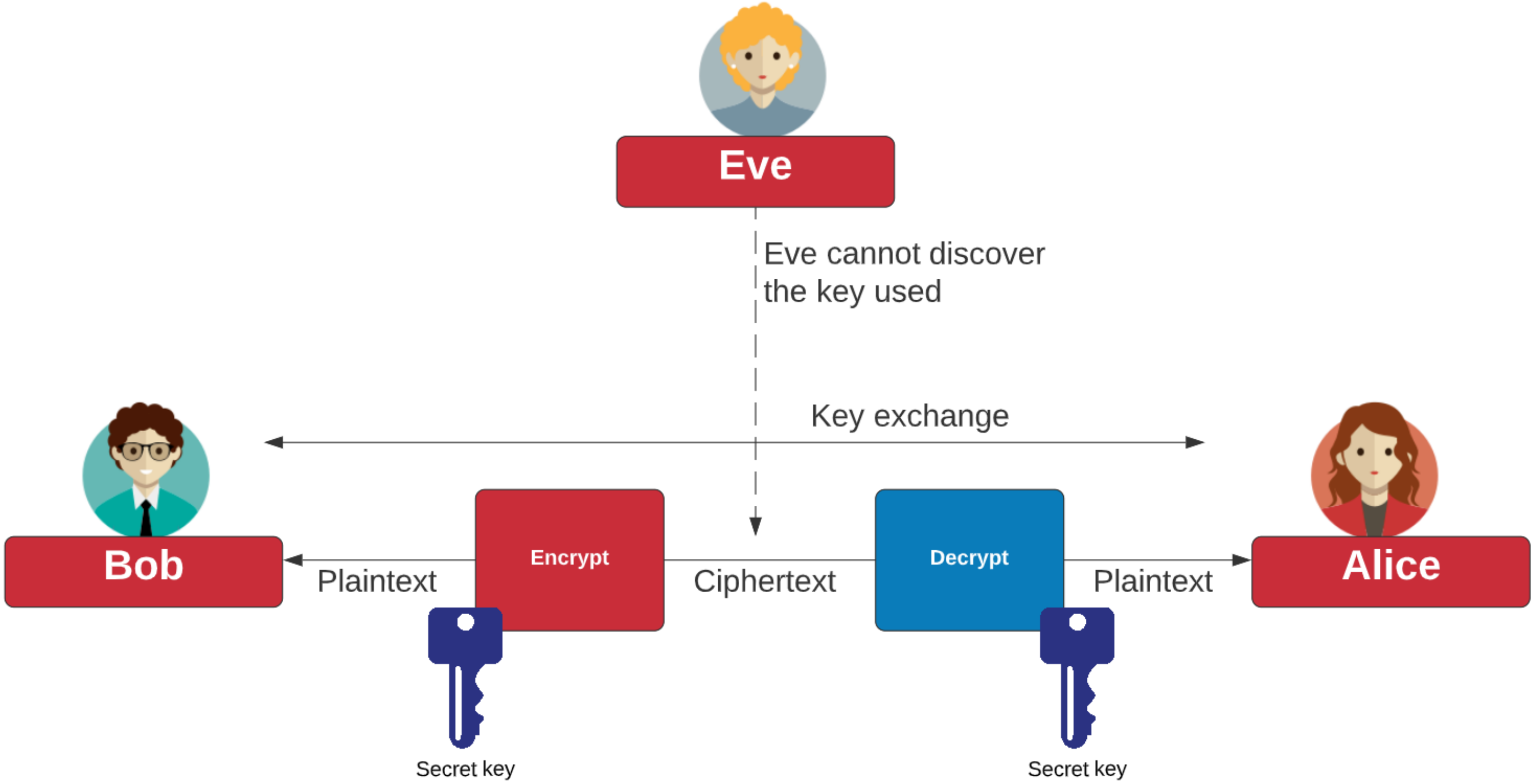
$g^a \pmod p$

$B = 5^7 \pmod{97}=40$

$A=5^9 \pmod{97}=30$

$\text{Key} = 30^7 \pmod{97}=51$

$\text{Key} = 40^9 \pmod{97}=51$



Eve
Eve cannot discover the key used
Key exchange
Bob
Plaintext
Encrypt
Ciphertext
Decrypt
Plaintext
Alice
Secret key
Secret key

Diffie-Hellman Generator

$$Y = g^x \bmod p$$

p	11							
Generator	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
x	**g^x mod p**	**g^x mod p**	**g^x mod p**	**g^x mod p**	**g^x mod p**	**g^x mod p**	**g^x mod p**	**g^x mod p**
2	4	9	5	3	3	5	9	4
3	8	5	9	4	7	2	6	3
4	5	4	3	9	9	3	4	5
5	10	1	1	1	10	10	10	1
6	9	3	4	5	5	4	3	9
7	7	9	5	3	8	6	2	4
8	3	5	9	4	4	9	5	3
9	6	4	3	9	2	8	7	5
10	1	1	1	1	1	1	1	1

Picking G

Diffie-Hellman Generation

```
C:\> openssl dhparam -out dhparams.pem 768 –text
C:\> type dhparams.pem
Diffie-Hellman-Parameters: (768 bit)
    prime:
        00:d0:37:c2:95:64:02:ea:12:2b:51:50:a2:84:6c:
        71:6a:3e:2c:a9:80:e2:65:b2:a5:ee:77:26:22:31:
        66:9e:fc:c8:09:94:e8:9d:f4:cd:bf:d2:37:b2:fb:
        b8:38:2c:87:28:38:dc:95:24:73:06:d3:d9:1f:af:
        78:01:10:6a:7e:56:4e:7b:ee:b4:8d:6b:4d:b5:9b:
        93:c6:f1:74:60:01:0d:96:7e:85:ca:b8:1f:f7:bc:
        43:b7:40:4d:4e:87:e3
    generator: 2 (0x2)
-----BEGIN DH PARAMETERS-----
MGYCYQDQN8KVZALqEitRUKKEbHFqPiypgOJlsqXudyYiMWae/MgJlOid9
M2/0jey
+7g4LIcoONyVJHMG09kfr3gBEGp+Vk577rSNa021m5PG8XRgAQ2WfoXKu
B/3vEO3
QE1Oh+MCAQI=
-----END DH PARAMETERS-----
```

- **DH Group 5**: 1,536 bit prime.
- **DH Group 2**: 1,024 bit prime.
- **DH Group 1**: 768-bit prime.

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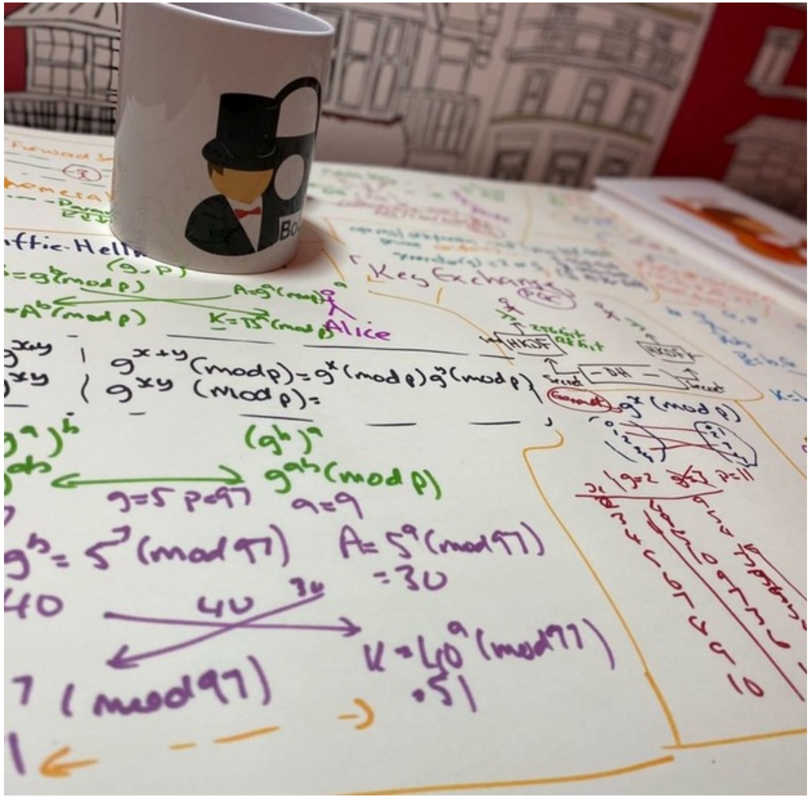
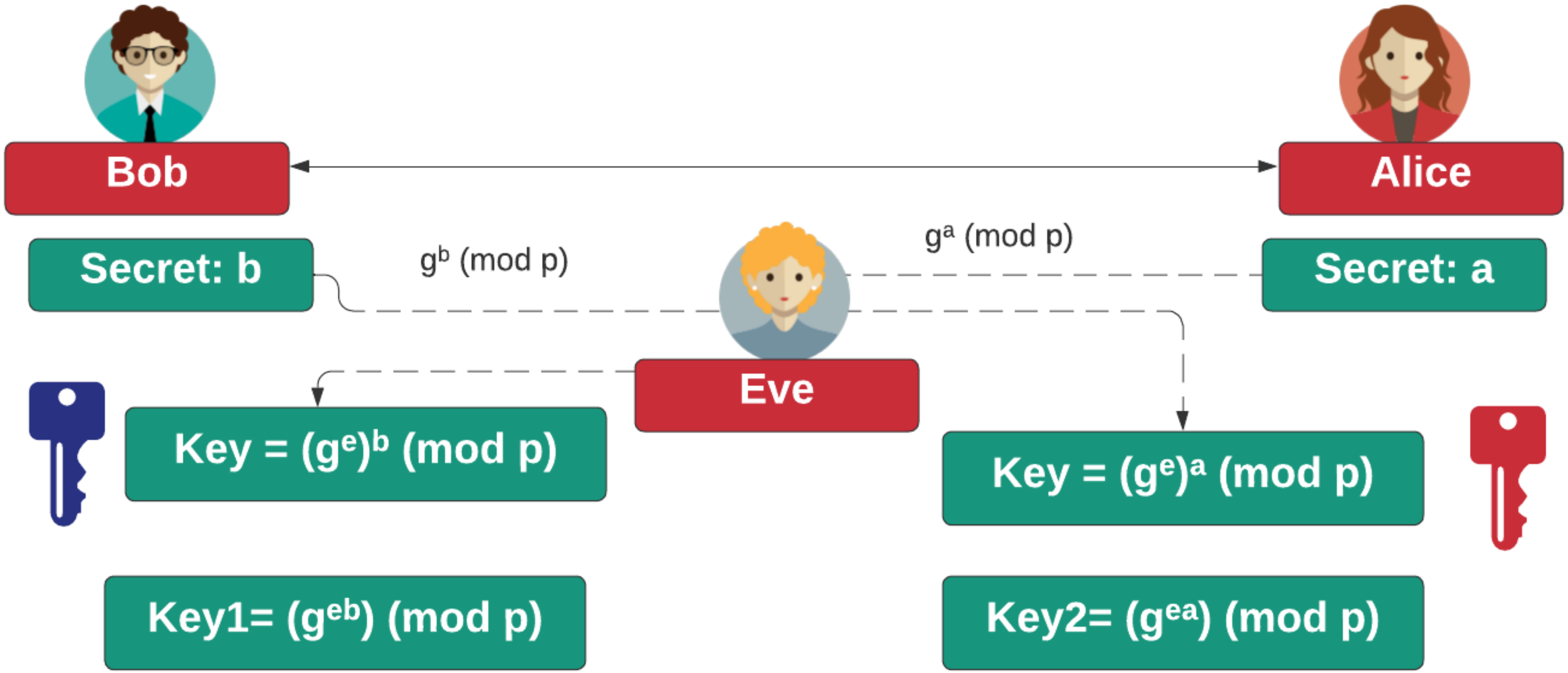


Diffie-Hellman Weaknesses

- In 2015, a paper entitled *Imperfect Forward Secrecy: How Diffie-Hellman Fails in Practice* – showed that it was fairly easy to precompute on values for two popular Diffie-Hellman parameters (and which use the DHE_EXPORT cipher set).
- The research team found that one was used as a default in the around 7% of the Top 1 million web sites and was hard coded into the Apache httpd service. Overall, at the time, it was found that over 3% of Web sites were still using the default.
- Diffie-Hellman-Parameters: (512 bit)
- prime:
- 00:9f:db:8b:8a:00:45:44:f0:04:5f:17:37:d0:ba:
- 2e:0b:27:4c:df:1a:9f:58:82:18:fb:43:53:16:a1:
- 6e:37:41:71:fd:19:d8:d8:f3:7c:39:bf:86:3f:d6:
- 0e:3e:30:06:80:a3:03:0c:6e:4c:37:57:d0:8f:70:
- e6:aa:87:10:33
- generator: 2 (0x2)

Eve-in-the-middle



Bob

Alice

Secret: b

g^b (mod p)

g^a (mod p)

Secret: a

Eve

Key = $(g^e)^b$ (mod p)

Key = $(g^e)^a$ (mod p)

Key1= (g^{eb}) (mod p)

Key2= (g^{ea}) (mod p)

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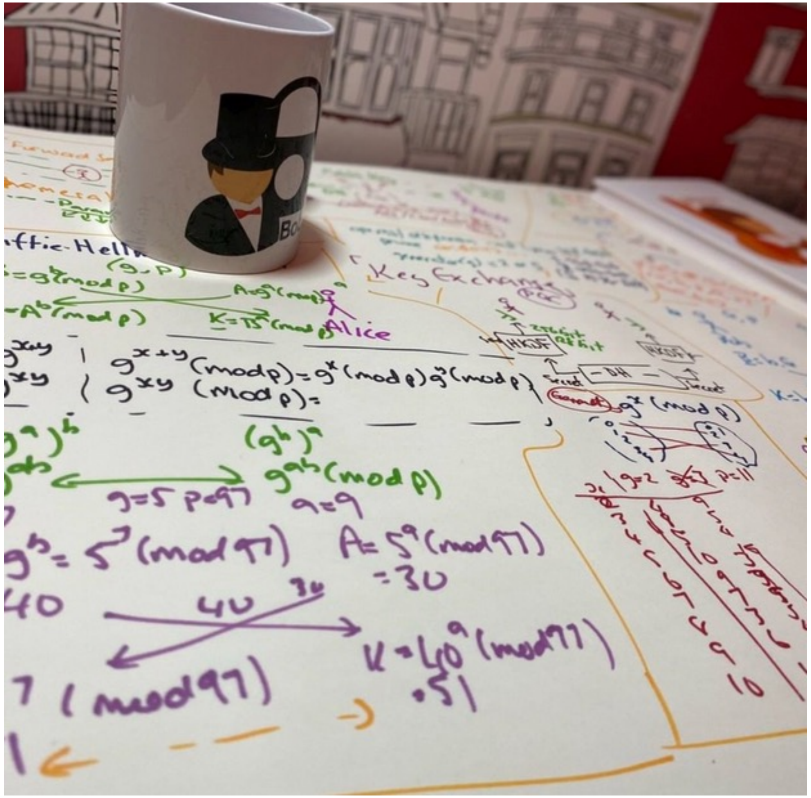
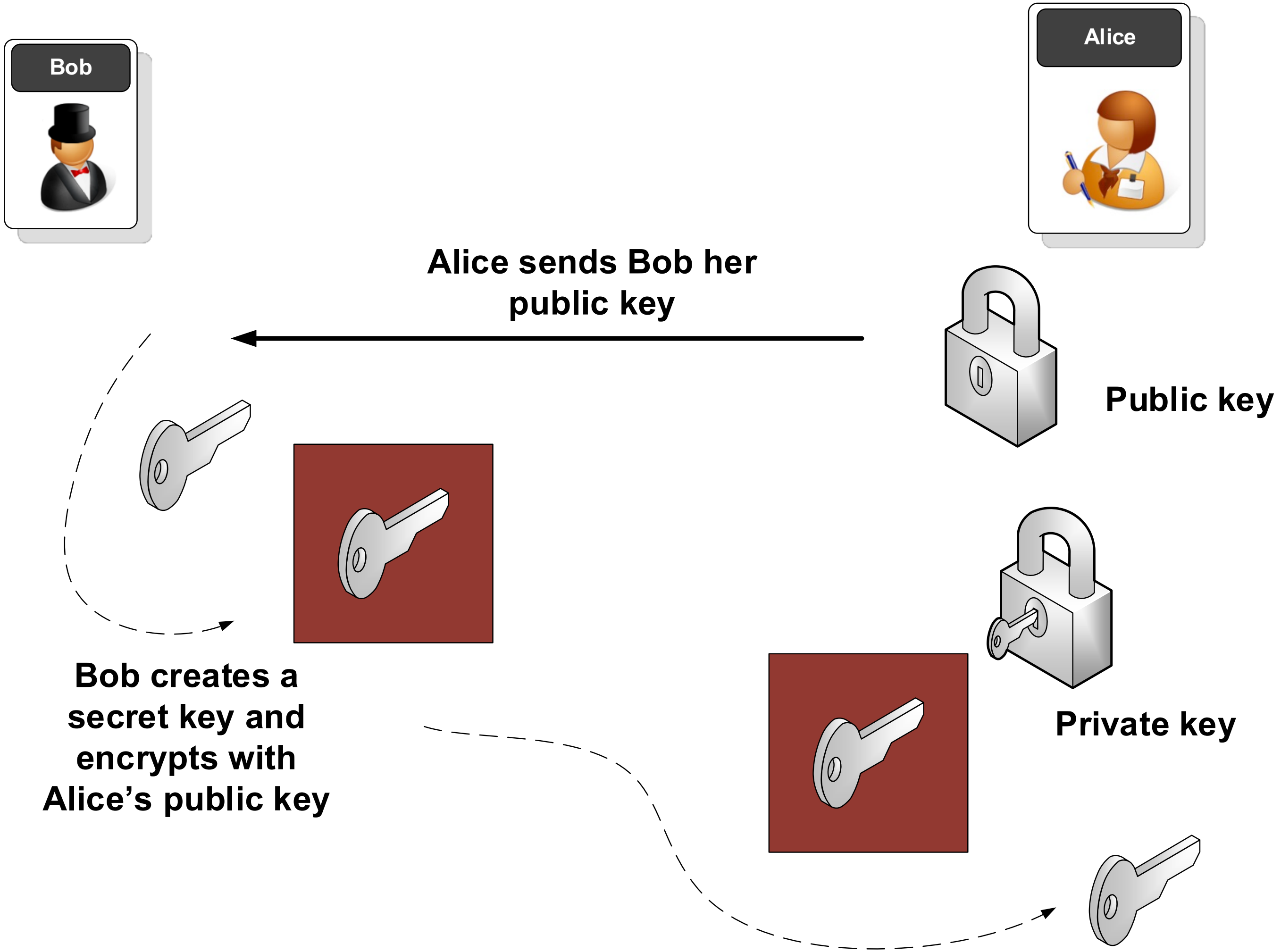


Key Exchange with Public Key



Alice sends Bob her public key

Public key

Private key

Bob creates a secret key and encrypts with Alice’s public key

Alice decrypts with her private key

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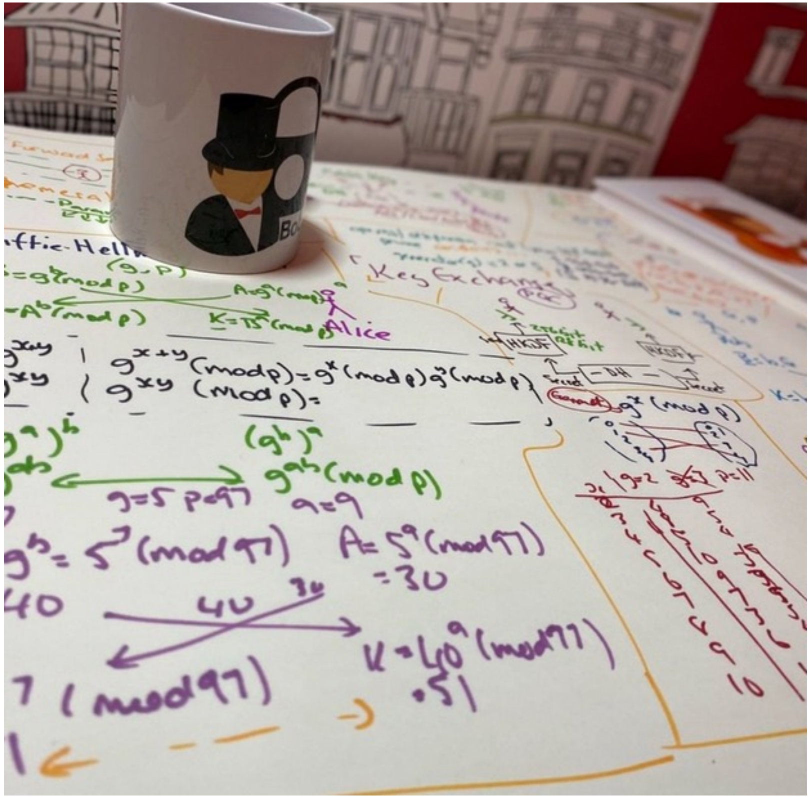

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