Xtreme9.0 - Xtreme In Security

An editorial that provides an approach for solving this problem is included at the bottom of this page.

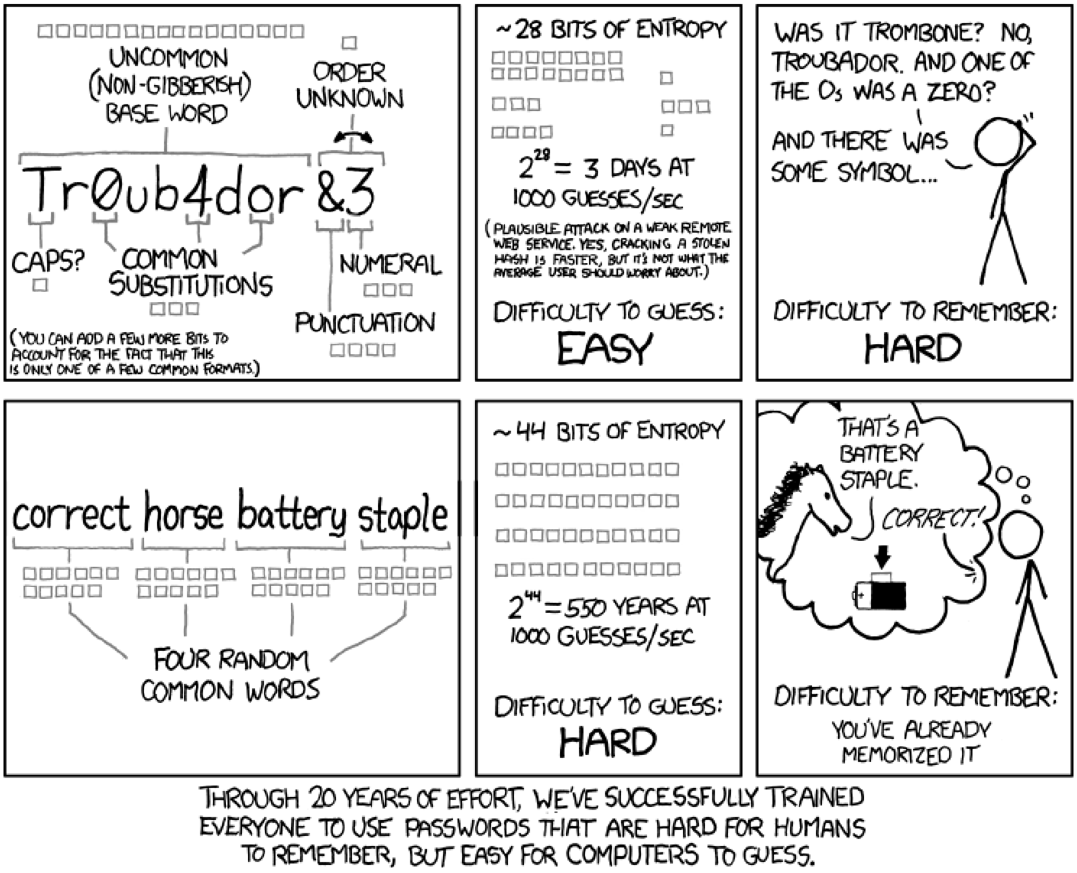
The Xtreme In Security Corp. has devised a password-based authentication system for their new operating system. They have made some unfortunate design decisions that make their system vulnerable to attack.

The system stores in a file a salted and peppered password hash. All of the passwords use the same salt "IEEE" and the same pepper "Xtreme". When the user is enrolled, they supply a password *p*. The system checks to make sure that *p* is less than 20 characters long, and that it contains only lowercase letters and numbers. Then the salt is prepended to the password and the pepper value is appended. The resulting value, using UTF-8 encoding, is then put through the SHA-256 hash algorithm, and then base64 encoded. This base64 encoded value is stored in a password file, along with the user's name.

Note: Even though the password contains only lowercase letters and numbers, the salt and the pepper contain some uppercase letters. The SHA-256 hash algorithm is case sensitive.

When the user is authenticated, a similar process occurs. The user is prompted for a username and a password. Then the salt is prepended to the supplied password and the pepper is appended. The resulting value is hashed with SHA-256, and base64 encoded. If the resulting value matches what is stored in the password file for the specified user, then the authentication is successful.

Your task is to break as many of the hashed passwords as possible to try to convince the system designers to improve their approach. Here is some inspiration from XKCD:


UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor &3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)
~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS: EASY
WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER: HARD
correct horse battery staple
FOUR RANDOM COMMON WORDS
~44 BITS OF ENTROPY
2^44 = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS: HARD
THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER: YOU'VE ALREADY MEMORIZED IT
THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

Credits: XKCD

Input Format

The input will consist of a single salted, peppered password hash. This hash will be derived from a single password.

The hash will be chosen from the following set of values:

```
/PtjJboZGlsmTovvyOhBOoTVnQKUP/gJXxjLAW9Lppw=
05HwH93tksb69U1ifesCQuYFP+gKPVH2L6W8JeBdXy0=
0BkyqI3NHyjh0m20wNt6txW08dglSMP4/qzUEezq4Aw=
1mT5cdKRz4BbfMdc8LAdnxfjsGO4lV0k0/V1IHtidmY=
28AdfW0JHmCP4TbieGON8dafRaFpUgpzuX2bHZN6WsM=
3hoie8omUyvM/9Qfx9dKfoptlwemYe2os8aohTGzoyw=
3uDaglIdYUn11AadEhELBjE15A0L6hAaWnZmjCGtt+M=
4D4NstIYSjVN826Q+SXUDDmXglJplpYWiJYf9rt7H8U=
7FCsEXCDTAxyLh3EPnNx7YrJ44SzehQYv3GmPSA6pWk=
81X3NN5JgTuGgqq3ErF0eL/l/wZFYkCwur6fZ06L2Us=
8FzGA/nS7XizLrAVOr/FoeKSq4gaoQRq+kpBKNXHIzc=
8OtpJ+E1XHv2RDsKIEwJc9KUFwPRzaqeHJ735Er6AVE=
8cdgZu9dBOrcTBMqElM+y9Vh5FTBRQ7n9EGa/4qVHUk=
8esDbw8ZVmUuUMEy2Scf5qGiZYiykevrvKpq2bVYHj4=
9DS4orbhPFbjJcosEqQg+eg0Si5qSOnftfHiqK8sYug=
9XDFIu4RPH0EL5XR+5VYILJ3UFAyltpfjONJKp/vcLk=
B2E/K/DywbLEKutOKpS8HxHFrZwucwac4KjzYgsXg3g=
BJQeqlV+4ejv0je5GpekzGdHHWHL5nnrbtD/170LZCA=
BjQiH/A2FUNHlUwhBi8NWmj3HmhmAh6Ag0kRyVSaVo8=
BwbAsOqPsxteVCpAwIjrhYogsUS1bF/bLns2QdcLYUI=
CYDZabjeyTAwcEDEcvrX83514UmpjzvQUQ68DIZ/PXg=
CornANxoZ5FJnlhwHmK42CDXf3h6jFr3g73YIRuoymQ=
DDa2TJX20pPsNftfyJ3s6LBwSMSR3EADZGDxW2wThbs=
FFXy3vru2D8rTWZRlh9lSMvtEusfWgO17OmJCTQTECs=
FGkqFC/jLDqDZ10fql1nGw7AQNWioOrZ3ydEaJyXBwo=
Fz+Y0H/R2rMZlc1C88Yx0A0xluYnVTinlw5qaSx8vWQ=
GcJMWMDF6+f+onf6oi1FbpnN7dVrFEZnlXtHqmaygs4=
GsXTQM0w+Clb1c9B7n28mADU2quLeI1n91KTyBboeHI=
HLnuqQmCYetzrau3frCDEpZ52QCIby108gugsmwAwQ0=
HWv9gx+GL/6g+0b0eOc+1Z/8BHse91/5T/DdiDwEknU=
IDB/pOthrWobzapJ/N8HsraNhwfbExAa2uusdiKHFFI=
IXYqlHbVeONERbxFe8SaEPEEKex45EihiC/l8CR52kk=
Idvs4Al9YZsqPG8xkSxVqb6MOVhbw5k+qtF8UZKYVE8=
IxQxcFXR51q8h8FLblPhYfUR30lIAt6hX8TjZWVa/GE=
JCmqBN0MsW13tEmsQPYWg9Fj25MUrqFYvSK2arxTt0A=
JOXxLH/i8i+fxDIWP2cts5Si/5En1A8M3s/vy6Aadic=
KudA8vCEQdGaaCSxotpAcluXnVPS3MAZPkwI/lVupak=
LGZEfbUr/tMREpJtsao/uuewcJXApmgfHDbh1zzfdhU=
LZIzmWEqXDPJsnKttFGRaG/jUhHrbTEKt1XCO6XbdME=
Lq0kV5M0HDSgB4m5KZbbn6BYRNlkKfaaAr3/11ueopY=
Lqxt1UjT1ecV6ucgYn+yrGSUTxPWkZgdDtbygGwC/BA=
MHQTB1MSsvhBxMpdRUiaM9Uj1QxU7zYq3FqDlW2HT2s=
MKewBZryb2l36Y0tDyx+WuVeXUGfiSzcJplm9y1w9m0=
N5aunKGHeN2WETLXLzfhfCxAfkwtGU/imziiTF3t7oY=
NmrOUzHxKSfNT8UJ1YXbRL8I+HCAb+glJ0bBXcHfagE=
NnSS+AuW1Z6zytSfqaiIVp4xxHHe70Av+IdhDlkoItQ=
O9L1ZWYwuzgaImTjOwuogXfpC+C44zzcDhpt08LjR5c=
R/ye+L9W+l6hyZ/v1POsWYboEGemIisARL8ohUvfBLI=
R1v9fEb9VrZuU5xiYTKTqhHF03VtXg7+KtfFHPkQuCQ=
RVfhsLovxa+/6tWgeSBASIIkzXkVtDPT4yYvjboHhIk=
Rz38Ng2qI3mPkaRB6uDoCYmmfzbVTCzpt2sG1o+TZqo=
S98FBzlv2vMVP/q+23m1wrHMJIrcy1rhoQGy338c4Bs=
SzraQWWasG5ZO1tJq16DqU/7M/o/WRiAWRl1aFFvwr8=
TInfNYwXvofBA+9QIe3+XEfDpO5ER+R+Jn3BOshhZWU=
VDkcRd54BhYlK5Wg2PPDa/jzGrSkMepGIv6Tw3I2ksc=
VjFTqTEY27V8lK2yCvhLhYm2Brh9bN1vWckVaevsiiY=
Wau4ReopjFKk8SYYNq5lIBL+Rgg8aBR6h9UgTIv2u7I=
XtEWsXf16y6Bc7vQxDy7hwRdBVWo3dV9C6CDVSf4PLs=
Y5b6UztMueFYIFMl4a61jlD/ZhFG74/rVn8XaqqU+8c=
YollqBlewcxE/kF6PKvv0r1CLZkKx82657bB0eQbiK0=
YzSqlQTtq5j+Kd+hW1ISgBW0mn61vsQsxNeipq0sYCo=
aJIH+q0YjYZCpierKtbue5JDtZSF8tKxVKuHYUPQ65k=
bi6rh2HgTbJxR2GOTNWZLlxiiWZVnObptGj0KqOCSYo=
cX7VyMvSYhuRvEfAUb3uNh8kmjpNFg0tatUPN562iOg=
eSCTiCrzHPbngPu3F4ivPkLUv7MqLUlmWAhA4UO975Y=
eUqkcVCbgIx1bGhhmnN5MxJFJhVruINmG65TjT/EQ1k=
gE7PseB3mspPtYG3JROzT9FeqTfPFYQvBF2SJD9V19Y=
gMi4hC4o7Fmv6yIrU48BVy8I1khXwkaD36G7bWiZHeo=
h84yifAWGLj9sakEqxZ3QEjkXL42AoScP3L5Tdevm98=
hEGKCiTZSA5x560hodRoIBBTE8pv4sP1VXG4D0fXWcI=
ix+0IJIpLpHeSHEII+Q/IVY+FlRXn3xMA0ey6UITi34=
j2GTUqtqZpotY8wF16zkvnbdCLTnX3oOZ30SjQUnIUk=
jtUg00EsmzzFkk8JgKg3OpkmPRpN9xbwsdNXQSPczwo=
k1J9Dv3EI442CO6A2FGN1H8JgFO2kjNBvkjDR0WIvkA=
kuRpkIh9kaNz6XvG8U6GO/IARH/SqhRnTiJbZHXC0yQ=
lFgqRrqTz1WXmO22u+Is1ZmWWUtuYrTJigsSB7I9NHI=
lUfxHX9xH2aOHheMMqQF+f5BNh97avew2uOwEN3B7HE=
m0IeuugWDOl9cFUFRYJhouCBT39T0dpp1xBOKPqHP94=
mgA5kgALstQpGUBp4vZ8oiz0P4jjAGl0wjgls6kQyMA=
nMAwaDYvEIAwoqtqWMpBAWdhuRgRq/fmwWbRM7cOMIU=
opBtoC66YDRbLNqZAAu2FIeKfF0HMOGHCOCPYeNHdx4=
ot/igM+me4e3UTT731qcBkSAcToyADMCddr7i7LCWGo=
qrkd/8imuRtiDb9N1w2hQRxJAkdx3Wqh1HVXPS7dym8=
r6BN0tdyAYZD0Nmc7bfV0WRcFBb1A2WIPPKHVRG59k8=
rdALvOYVhA3hnUTBlaQXigWBSgMYzGTreSKyMoAoKfw=
rjwtKqkPc7cfQ+zZ+E9c+fzQYhRvhVtaKEFb+srIHcQ=
rwvmTDiJxIEETbsngvpxYGwZZK+FGo7527odGuQUjtQ=
socJeO02bT2w+XZUrLoopbZvQ1lRhDfE88GVrJQ8p+g=
tDdmKQpMiVDFA1YdblkHSFzL4Z9UIQ9FSouf3TybOu0=
tojYiNtlWmq+7r1dSvxDk3W5at/NMAi1uxCHY61WAKk=
tqpGCBzhR+0ONFk1sBiHPhz+kRiXmY3CGdUXqnMJwLg=
uAZthS7b4ySZtWpM9pJ7ulYnhFdpFABpR2iPRQEmff0=
uCG9dSBejCOrZWsX7+u8G340p74s8lDS/El8MIeOyMo=
ugcIIpDID0R1uFqBAcN3PNXhwlhen77GdAccFgpbs+A=
usg8BTtSfewL5M3OVg91TJCTc5vONLqgUCC/Si1Grsg=
vs2sCU8qG0pDYQfcjlPzDzvcbJnhP1OgFRcXP4i3ffw=
wEtqAs8JHjicWnXshAWF5Sg6NoswuG9qeJ7USw7YD7c=
y+zbMpySKY+WF97KkgRQ+tBpM7iTqTj9guWmGJcqfyA=
y1R6JQiUzUovgtdrvCkbeQAyMhFoupzhI5ZuQVPfCgw=
zqKPAOt5ziHSeRxc0TgUZF3rJxzBHAKdJeccvt3F7Jg=
```

Output Format

The output should consist of a single alphanumeric string, which hashes to the corresponding value given in the input.

Note: You may not be able to break all of the hashed passwords. If you are given a hash that you cannot break, you may output an arbitrary string. You will earn partial credit for this problem for each password that you do crack!

Sample Input

```
tDdmKQpMiVDFA1YdblkHSFzL4Z9UIQ9FSouf3TybOu0=
```

Sample Output

```
password1
```

Explanation

For all passwords, the salt value is "IEEE" and the pepper is "Xtreme". First, we can take the SHA-256 hash of the UTF-8 encoded string `IEEEpassword1Xtreme`. If we then base64 encode the result, the value equals the desired value: `tDdmKQpMiVDFA1YdblkHSFzL4Z9UIQ9FSouf3TybOu0=`.

Editorial

There are an enormous number of possible passwords, using lower case digits and numbers, of length less than 20. A exhaustive search of all of these would not be possible during the contest. However, there are a reasonable number of passwords with six or fewer characters. An exhaustive search can easily be performed on these passwords.

If such a search were done, you might notice that there are 1-character passwords `0`, `1`, `3`, `4`, `a`, `e`, `i`, and `o`. Moreover, just like in the cartoon, many passwords include common vowel transformations using these characters:

- `4` for `a`
- `3` for `e`

- `1` for `i`
- `0` for `o`

You might also notice that passwords optionally have a single digit appended to the end of them (also as described in the cartoon).

The key observation, though, is that all of the words used as passwords come from the IEEEXtreme 9.0 problem set. If you were to create a dictionary with all of these words, you should be able to crack all of the remaining passwords.