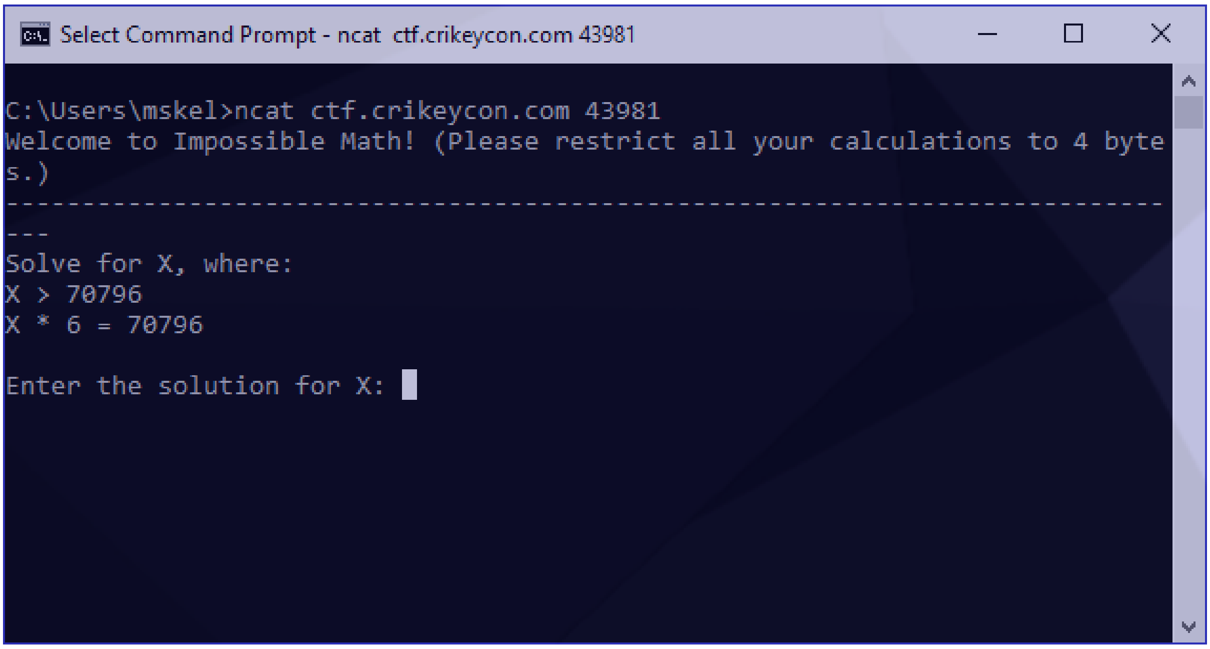
CrikeyCon 2017

Impossible Math Solution by Michael ‘codingo’ Skelton

Category: Coding
Points: 400
Solves: 7
Description: ctf.crikeycon.com:43981

Probing the host

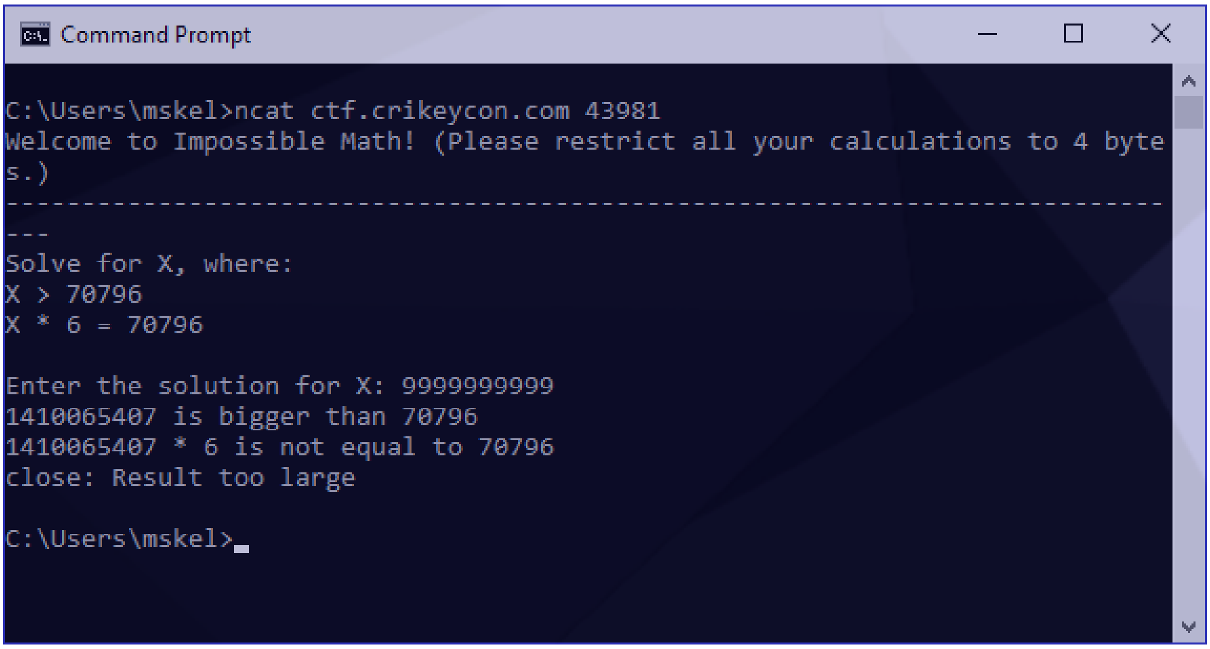
Before doing anything else on this host I attempted to ncat to it, receiving the following:



```
C:\Users\mskel>ncat ctf.crikeycon.com 43981
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
-----------------------------------------------------------------------------
---
Solve for X, where:
X > 70796
X * 6 = 70796

Enter the solution for X:
```

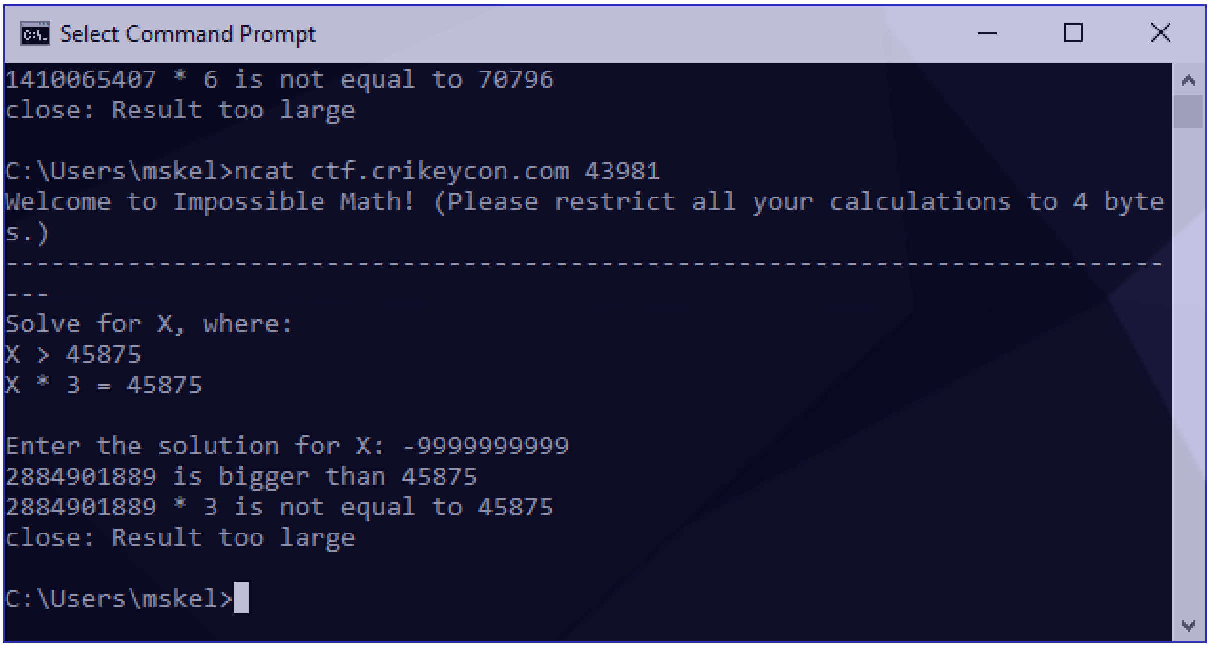
Identifying the core problem

Since the math is impossible there’s likely a trick here. With that in mind I figure we need to overload an operator (integer overflow) and try passing a large number as input:



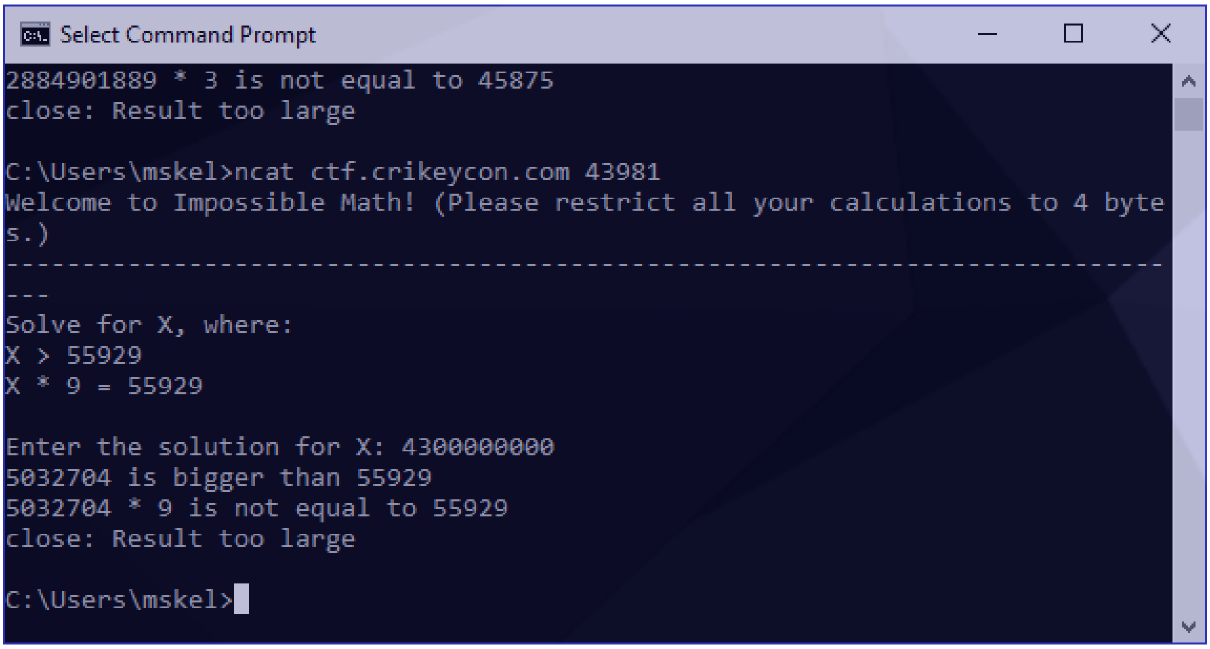
```
C:\Users\mskel>ncat ctf.crikeycon.com 43981
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
-----------------------------------------------------------------------------
---
Solve for X, where:
X > 70796
X * 6 = 70796

Enter the solution for X: 9999999999
1410065407 is bigger than 70796
1410065407 * 6 is not equal to 70796
close: Result too large

C:\Users\mskel>_
```

Awesome! Our integer overloads by wrapping around. To gather a bit more information I also tried an integer underflow:



```
1410065407 * 6 is not equal to 70796
close: Result too large

C:\Users\mskel>ncat ctf.crikeycon.com 43981
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
----------------------------------------------------------------------------
---
Solve for X, where:
X > 45875
X * 3 = 45875

Enter the solution for X: -9999999999
2884901889 is bigger than 45875
2884901889 * 3 is not equal to 45875
close: Result too large

C:\Users\mskel>
```

The same result. I now had to identify the figure we wrap around. These numbers are a bit irritatingly long to work with so I tried something a bit smaller to see if I could something more manageable:



```
2884901889 * 3 is not equal to 45875
close: Result too large

C:\Users\mskel>ncat ctf.crikeycon.com 43981
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
----------------------------------------------------------------------------
---
Solve for X, where:
X > 55929
X * 9 = 55929

Enter the solution for X: 4300000000
5032704 is bigger than 55929
5032704 * 9 is not equal to 55929
close: Result too large

C:\Users\mskel>
```

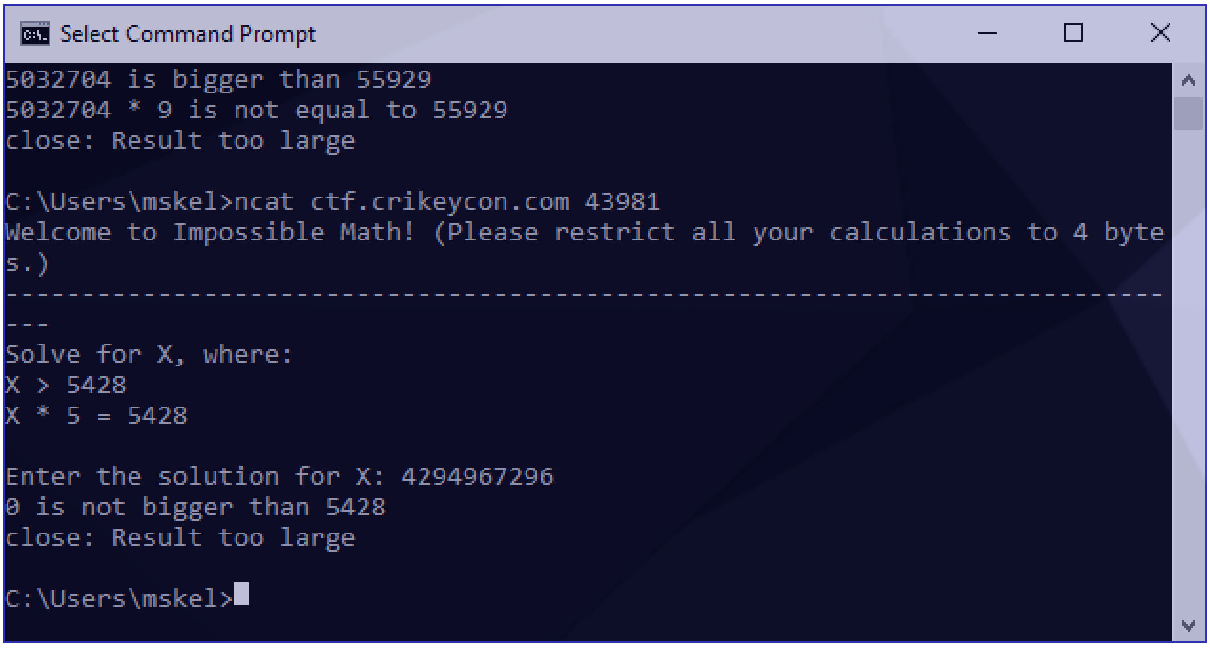
We can use the following to identify our overflow point:

$$overflow = input - result$$

$$4294967296 = 4300000000 - 5032704$$

4294967296 is exactly 2^32, which is 1 beyond the maximum supported by unsigned int (32 bits), further supporting our case that this is an integer overflow exercise.

To validate this, I should be able to pass this value to any problem and receive 0 back as a response (as it will reach the signed amount and loop back once), as follows:



```
5032704 is bigger than 55929
5032704 * 9 is not equal to 55929
close: Result too large

C:\Users\mskel>ncat ctf.crikeycon.com 43981
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
--------------------------------------------------------------------------
---
Solve for X, where:
X > 5428
X * 5 = 5428

Enter the solution for X: 4294967296
0 is not bigger than 5428
close: Result too large

C:\Users\mskel>
```

For the remainder of this exercise I'm going to refer to the variables from our second-last screenshot as the following:

$$x * 9 = 55929$$

$$x * multiplier = destination$$

Since our number wraparounds we now know we need a number with the following conditions:

- Our overflow must be lower than 4294967296 but higher than our $destination$ to pass the first condition.
- Our overflow needs to exceed 4294967296 when multiplied by the $multiplier$ and result in the $destination$

Calculating the correct overflow

We can calculate our overflow using the following:

$$overflow = \frac{(2^{32} + destination)}{multiplier}$$

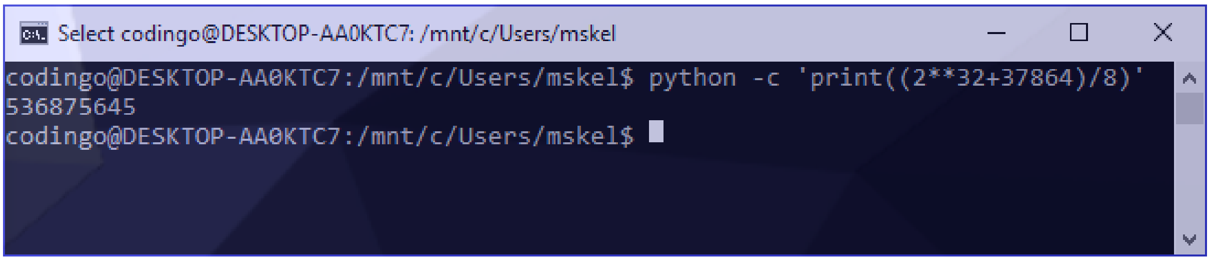
I turned this into a proof of concept by generating a new ncat session, which asked the following:

> *Solve for X, where:*
> *X > 37864*
> *X * 8 = 37864*

To generate our answer, I used the following:

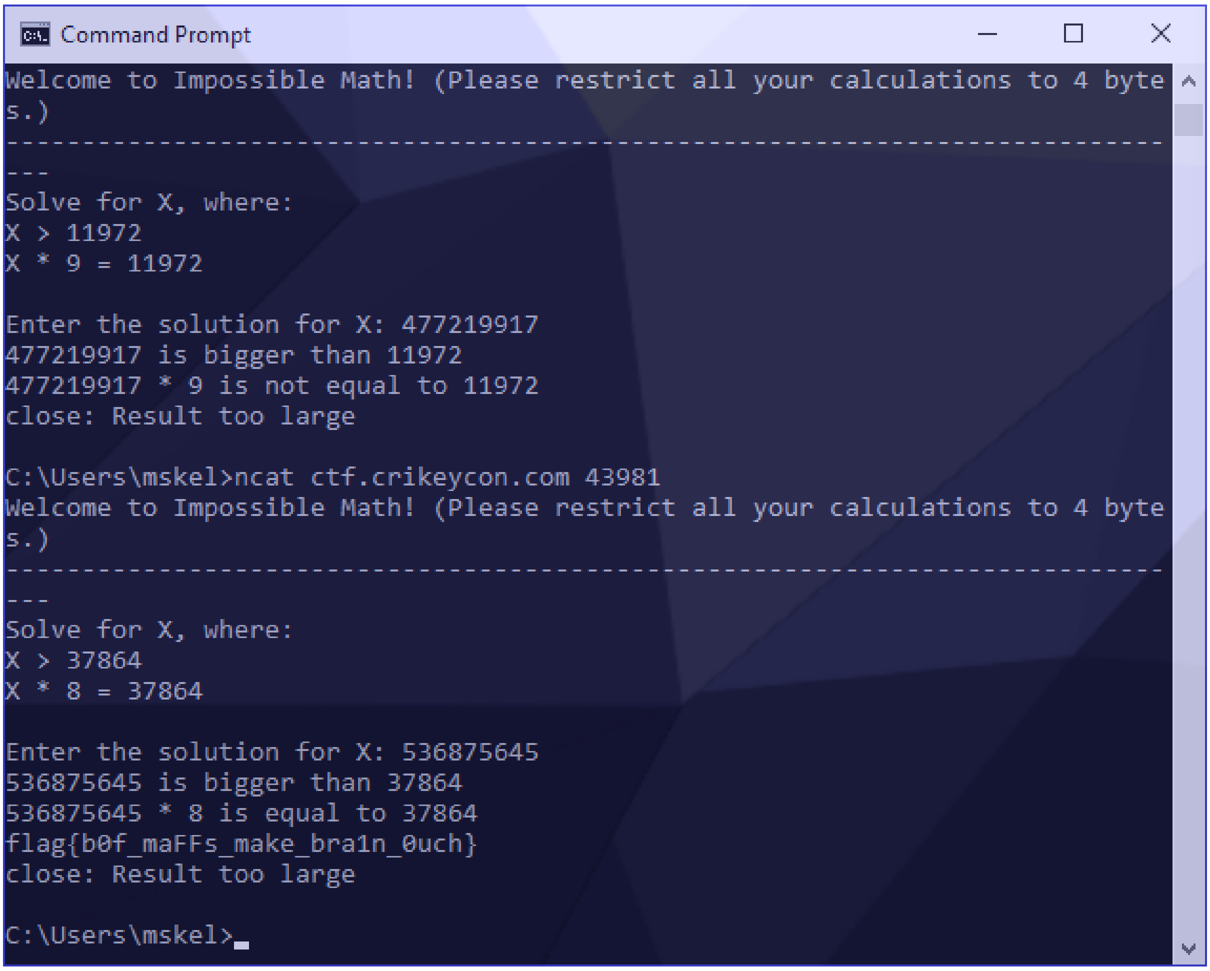
```
python -c 'print((2**32+destination)/multiplier)'
```

This generated the answer of 536875645 as follows:



```
codingo@DESKTOP-AA0KTC7:/mnt/c/Users/mskel$ python -c 'print((2**32+37864)/8)'
536875645
codingo@DESKTOP-AA0KTC7:/mnt/c/Users/mskel$
```

Under some circumstances, we would then be able to pipe our answer into a new ncat session but since our variables change on each connection we need to do this manually to verify it's correct:



```
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
-----------------------------------------------------------------------------
---
Solve for X, where:
X > 11972
X * 9 = 11972

Enter the solution for X: 477219917
477219917 is bigger than 11972
477219917 * 9 is not equal to 11972
close: Result too large

C:\Users\mskel>ncat ctf.crikeycon.com 43981
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)
-----------------------------------------------------------------------------
---
Solve for X, where:
X > 37864
X * 8 = 37864

Enter the solution for X: 536875645
536875645 is bigger than 37864
536875645 * 8 is equal to 37864
flag{b0f_maFFs_make_bra1n_0uch}
close: Result too large

C:\Users\mskel>
```

Success! Our flag was revealed.

Creating an automatic answer tool

Manual answers are great, but this is classified as a coding challenge, not a mathematical one!

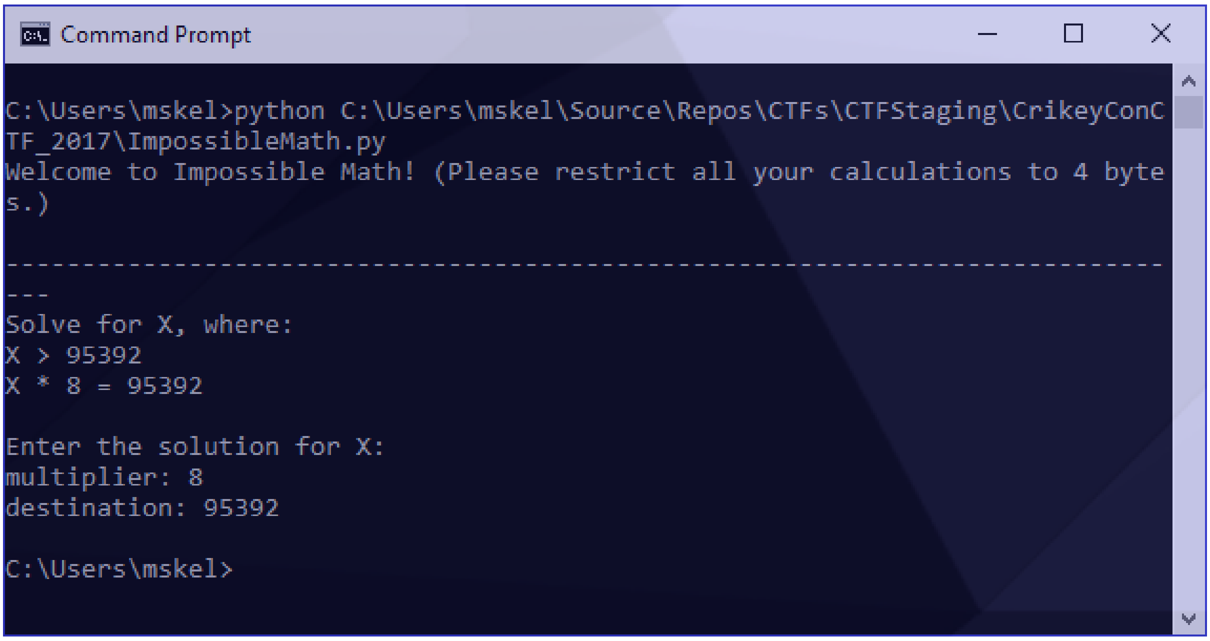
There are a few core processes to this part of the exercise. First is forming an open connection and identifying our destination and multiplier from the data that comes back. We've also been asked in the banner of our connection to limit our calculations to 4 bytes, so we'll make sure we limit what we request at a time.

Splitting our variables out of the calculation is quite easy. They're both present on the line reflected as:

$$x * multiplier = destination$$

We can use regular expressions to identify this packet stream from the equals sign, and then split our values out into capture groups using another expression. Putting this boilerplate together looks like the following:

```
#!/usr/bin/python3

import socket
import re
import operator
import sys

MAXBUF = 4096
SENTINEL = 'flag'
CTF_BOT = ('ctf.crikeycon.com', 43981)


if __name__ == '__main__':
    client = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    client.connect(CTF_BOT)

    while True:
        data = b''

        # receive and store data
        while True:
            chunk = client.recv(MAXBUF)
            data += chunk
            if len(chunk) < MAXBUF:
                break

        # store decoded data for future usage
        decoded = data.decode('utf-8')

        # print out response packet
        print(decoded)

        # our flag contains flag{}, once it's revealed print received data and exit
        if SENTINEL in decoded:
            break

        # skip loop until we see our X * Y = Z line
        if not re.search('[=]', decoded):
            continue

        # select integers and store into capture groups
        match = re.search('(\d+) = (\d+)', decoded)

        print('multiplier: ' + match.group(1))
        print('destination: ' + match.group(2))
```



```
C:\Users\mskel>python C:\Users\mskel\Source\Repos\CTFs\CTFStaging\CrikeyConC
TF_2017\ImpossibleMath.py
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)

----------------------------------------------------------------------------
---
Solve for X, where:
X > 95392
X * 8 = 95392

Enter the solution for X:
multiplier: 8
destination: 95392

C:\Users\mskel>
```

Great! We now have what we need in a variable. Referring back to our formula above, we now need to calculate:

$$overflow = \frac{(2^{32} + destination)}{multiplier}$$

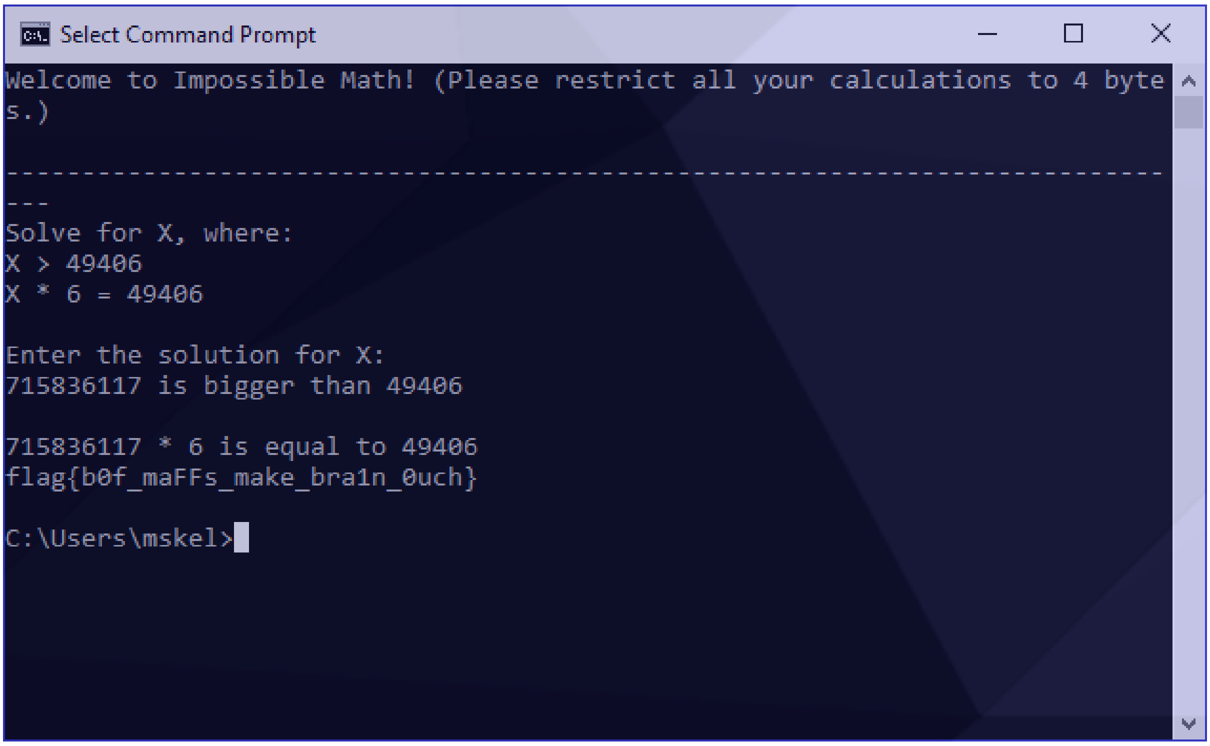
This will look like the following (note that we cast our regular expressions back to integers to prevent operand exceptions):

```
multiplier = int(match.group(1))
destination = int(match.group(2))
overflow = int((2**32+destination) / multiplier)
```

Final Script

Putting it all together we then have the following:

```
#!/usr/bin/python3

import socket
import re
import operator
import sys

MAXBUF = 4096
SENTINEL = 'flag'
CTF_BOT = ('ctf.crikeycon.com', 43981)


if __name__ == '__main__':
    client = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    client.connect(CTF_BOT)

    while True:
        data = b''

        # receive and store data
        while True:
            chunk = client.recv(MAXBUF)
            data += chunk
            if len(chunk) < MAXBUF:
                break

        # store decoded data for future usage
        decoded = data.decode('utf-8')

        # print out response packet
        print(decoded)

        # our flag contains flag{}, once it's revealed print recevied data and exit
        if SENTINEL in decoded:
            break

        # skip loop until we see our X * Y = Z line
        if not re.search('[=]', decoded):
            continue

        # select integers and store into capture groups
        match = re.search('(\d+) = (\d+)', decoded)

        multiplier = int(match.group(1))
        destination = int(match.group(2))
        overflow = int((2**32+destination) / multiplier)

        # encode and transfer
        client.send(str(overflow).encode('utf-8')+ b'\n')
```



```
Welcome to Impossible Math! (Please restrict all your calculations to 4 byte
s.)

--------------------------------------------------------------------------
---
Solve for X, where:
X > 49406
X * 6 = 49406

Enter the solution for X:
715836117 is bigger than 49406

715836117 * 6 is equal to 49406
flag{b0f_maFFs_make_bra1n_0uch}

C:\Users\mskel>
```

Success!