


```

n := n1;
ans := 0;
while n > 0 do
d := n mod bs;
ans := ans + f(d);
n := (n-d) / bs;
end do;
ans;
end;

```

```
onestep := proc(n1)
```

```
  local ans, n, d;
```

```
  n := n1;
```

```
  ans := 0;
```

```
  while 0 < n do d := mod(n, bs); ans := ans + f(d); n := (n - d) / bs end do;
```

```
  ans
```

```
end proc
```

```
> happy := proc(n)
```

```
  # returns -1 if not happy, and returns the number of steps to reach 1 if it is happy
```

```
  local m, j, height;
```

```
  m := n;
```

```
  height := -1;
```

```
  for j from 1 to 100 while (m > 1 and m ≠ 4) do
```

```
    m := onestep(m);
```

```
  end do;
```

```
  if m = 1 then height := j; end if;
```

```
  height;
```

```
  end;
```

```
happy := proc(n)
```

```
  local m, j, height;
```

```
  m := n;
```

```
  height := -1;
```

```
  for j to 100 while 1 < m and m <> 4 do m := onestep(m) end do;
```

```
  if m = 1 then height := j end if;
```

```
  height
```

```
end proc
```

```
>
```

Now to look for seven in a row. We claim the answer is the 234 digit number

$$3577 \cdot 10^{230} + (10^{228} - 1) \cdot 10^2 + 45$$

so we will check all $a < 170586$.

We first verify this value does give seven 3-consecutive cubic happy numbers.

```
> N := 3577 · 10230 + (10228 - 1) · 102 + 45
```

```
N :=
```

(3)

(4)

(5)

80, 3, -1

(8)

```
> a := 111333;
   ktop := iquo(a, 93);
   for k from 0 to ktop do # k is the number of nines at the end of N1.
     for d2p1 from 1 to 9 do
       # d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.
       if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
         - 1)3 + 93·k + 93 + 53) > 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k
           + 93 + 23)) end if;
     end do; end do;
```

a := 111333

ktop := 152

10, 3, -1

21, 9, -1

75, 6, -1

80, 3, -1

83, 2, -1

89, 9, -1

90, 9, -1

92, 3, -1

108, 8, 3

110, 1, -1

112, 4, -1

116, 5, -1

117, 6, 4

120, 6, -1

(9)

```
> 111333 + 108·93
```

190065

(10)

so the first one that works, k=108, gives a total much larger than the solution we have above.

```
> a := 157806;
   ktop := iquo(a, 93);
   for k from 0 to ktop do # k is the number of nines at the end of N1.
     for d2p1 from 1 to 9 do
       # d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.
       if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
         - 1)3 + 93·k + 93 + 53) > 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k
           + 93 + 23)) end if;
     end do; end do;
```

a := 157806

ktop := 216

12, 8, -1

29, 8, 4

45, 2, -1

53, 5, -1

182, 5, -1 (11)

> 157806 + 29·9³

178947 (12)

again, this will be larger than our solution above.

> a := 166428;

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2p1 from 1 to 9 do

d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.

if happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 8³) > 0 and happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 5³) > 0 then print(k, d2p1, happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 2³)) end if;
end do; end do;

a := 166428

ktop := 228

16, 2, -1

151, 8, -1

195, 5, -1

215, 2, -1

228, 2, -1 (13)

> a := 167175;

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2p1 from 1 to 9 do

d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.

if happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 8³) > 0 and happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 2³) > 0 and happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 5³) > 0 then print(k, d2p1, happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 8³ + 6³)) end if;
#note the 89 will automatically work
end do; end do;

a := 167175

ktop := 229

6, 2, -1

16, 5, -1 (14)

> 167175 + 9³·6

171549 (15)

> a := 167328;

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2p1 from 1 to 9 do

d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.

if happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 8³) > 0 and happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 2³) > 0 and happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 5³) > 0 then print(k, d2p1, happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 8³ + 6³)) end if;
#note the 89 will automatically work

end do; end do:

```
a := 167328
ktop := 229
41, 5, -1
```

(16)

> 167328 + 9³·41

197217

(17)

> a := 169246;

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2p1 from 1 to 9 do

d2p1 is the digit that precedes the k digits of zeros in the number ending with 00.

if happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 7³) > 0 **and** happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 4³) > 0 **and** happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 9³ + 1³)

> 0 **then** print(k, d2p1, happy(a - d2p1³ + (d2p1 - 1)³ + 9³·k + 8³ + 8³)) **end if;**

end do; end do:

```
a := 169246
ktop := 232
38, 3, -1
```

(18)

so none give three before the carry taht will yield a number with S(N)<170586. .

There are none with final digits 88 or 90. We now check the ones that had final digits 89 to see if they have three after the carry.

> a := 106736;

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.

if happy(a + (d2 + 1)³ - d2³ - 9³·k + 2³) > 0 **and** happy(a + (d2 + 1)³ - d2³ - 9³·k + 5³) > 0 **then** print(k, d2, happy(a + (d2 + 1)³ - d2³ - 9³·k + 8³)) **end if;**

end do; end do:

```
a := 106736
ktop := 146
```

(19)

> a := 126542;

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.

if happy(a + (d2 + 1)³ - d2³ - 9³·k + 2³) > 0 **and** happy(a + (d2 + 1)³ - d2³ - 9³·k + 5³) > 0 **then** print(k, d2, happy(a + (d2 + 1)³ - d2³ - 9³·k + 8³)) **end if;**

end do; end do:

```
a := 126542
ktop := 173
```

(20)

so neither of these has three after the carry.

Thus, our example above is indeed the smallest one with seven or more in a row.

Now for eight in a row.


```

    ktop := iquo(a, 93);
    for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
    if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
    + (d2 + 1)3 - d23 - 93·k + 1 + 0)) end if;
    end do; end do;

```

a := 169736
ktop := 232 (25)

```

> a := 171542;
    ktop := iquo(a, 93);
    for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
    if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
    + (d2 + 1)3 - d23 - 93·k + 1 + 0)) end if;
    end do; end do;

```

a := 171542
ktop := 235
6, 1, 4 (26)

```

> a := 171925;
    ktop := iquo(a, 93);
    for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
    if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
    + (d2 + 1)3 - d23 - 93·k + 1 + 0)) end if;
    end do; end do;

```

a := 171925
ktop := 235 (27)

>

We now check the possible five/three split from a=168517 with final digits 87. As we see here, we cannot have three cubic happy numbers after the carry.

```

> a := 168517;
    ktop := iquo(a, 93);
    for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
    if happy(a + (d2 + 1)3 - d23 - 93·k + 23) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 53) > 0 then print(k, d2, happy(a + (d2 + 1)3 - d23 - 93·k + 83)) end if;
    end do; end do;

```

a := 168517
ktop := 231
1, 2, -1
15, 0, -1
16, 8, -1


```

ktop := iquo(a, 93);
for k from 0 to ktop do # k is the number of nines at the end of N1.
for d2p1 from 1 to 9 do
  # d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.
if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
  - 1)3 + 93·k + 93 + 53) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 23)
  > 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 83 + 63)) end if;
  #note the 89 will automatically work
end do; end do:

```

a := 176931

ktop := 242

164, 2, -1

(32)

> 176931 + 9³·164

296487

(33)

> a := 177741;

```

ktop := iquo(a, 93);

```

```

for k from 0 to ktop do # k is the number of nines at the end of N1.

```

```

for d2p1 from 1 to 9 do

```

```

  # d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.

```

```

if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
  - 1)3 + 93·k + 93 + 53) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 23)
  > 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 83 + 63)) end if;
  #note the 89 will automatically work

```

```

end do; end do:

```

a := 177741

ktop := 243

194, 2, -1

(34)

> a := 197595;

```

ktop := iquo(a, 93);

```

```

for k from 0 to ktop do # k is the number of nines at the end of N1.

```

```

for d2p1 from 1 to 9 do

```

```

  # d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.

```

```

if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
  - 1)3 + 93·k + 93 + 53) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 23)
  > 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 83 + 63)) end if;
  #note the 89 will automatically work

```

```

end do; end do:

```

a := 197595

ktop := 271

26, 2, -1

204, 8, -1

241, 5, -1

(35)

> 197595 + 9³·26

216549

(36)

The only a values with five in a row with final digits 85, 86, 87 are these three:

```

> a := 178535; #final digit 86
  ktop := iquo(a, 93);
  for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
      if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
        + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
          + (d2 + 1)3 - d23 - 93·k + 1 + 0)) end if;
    end do; end do:

```

a := 178535
ktop := 244 (37)

```

> a := 196535; #final digit 86
  ktop := iquo(a, 93);
  for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
      if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
        + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
          + (d2 + 1)3 - d23 - 93·k + 1 + 0)) end if;
    end do; end do:

```

a := 196535
ktop := 269
117, 5, 4 (38)

```

>
> a := 195517; #this has final digits 87 as opposed to 86
  ktop := iquo(a, 93);
  for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
      if happy(a + (d2 + 1)3 - d23 - 93·k + 23) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
        + 53) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 83) > 0 then print(k, d2, happy(a
          + (d2 + 1)3 - d23 - 93·k + 1 + 1)) end if;
    end do; end do:

```

a := 195517
ktop := 268
26, 5, -1 (39)

so only 196535 has four after the carry, and indeed, it leads to our smallest example listed above.

Finally, to take advantage of the rest of the data, we search for ten in a row. Since we do not have six or more in a row with a carry (last digits 82, 83, 84 or 00, 01, 02) the only way to get ten in a row is a 5/5 split.

So we check all a values that give five in a row with final digits 00,01,02, or 85,86,87. There are three with a<500000 that have final digit 86 and four with last digits 00, 01 or 02. As we see here, none of these have five across the carry, so any example of ten in a row must have a>500000, hence more than 685 digits.

```

> 93·685

```

499365 (40)

```

> a := 337106; #final digit 86

```

```

    ktop := iquo(a, 93);
    for k from 0 to ktop do # k is the number of nines at the end of N1.
    for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.
    if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
    + (d2 + 1)3 - d23 - 93·k + 13 + 33)) end if; # the 10 works automatically
    end do; end do:

```

a := 337106

ktop := 462

60, 1, -1

209, 4, -1

310, 8, -1

(41)

> a := 395993; #final digit 86

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.

```

    if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
    + (d2 + 1)3 - d23 - 93·k + 13 + 33)) end if; # the 10 works automatically

```

end do; end do:

a := 395993

ktop := 543

141, 7, -1

(42)

> a := 496910; #final digit 86

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2 from 0 to 8 do # d2 is the digit that precedes the k digits of nine.

```

    if happy(a + (d2 + 1)3 - d23 - 93·k + 13) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k
    + 43) > 0 and happy(a + (d2 + 1)3 - d23 - 93·k + 73) > 0 then print(k, d2, happy(a
    + (d2 + 1)3 - d23 - 93·k + 13 + 33)) end if; # the 10 works automatically

```

end do; end do:

a := 496910

ktop := 681

32, 4, -1

(43)

>

> a := 373896; #final digits 01

ktop := iquo(a, 9³);

for k from 0 to ktop do # k is the number of nines at the end of N1.

for d2p1 from 1 to 9 do

d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.

```

    if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
    - 1)3 + 93·k + 93 + 53) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 23)
    > 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 83 + 63)) end if;

```

#note the 89 will automatically work

end do; end do:

```

a := 373896
ktop := 512
5, 5, -1
438, 5, -1
500, 2, -1

```

(44)

```

> a := 396720; #final digits 01
ktop := iquo(a, 93);
for k from 0 to ktop do # k is the number of nines at the end of N1.
for d2p1 from 1 to 9 do
# d2p1 is the digit that precedes the k digits of zeros in the number ending with 01.
if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 83) > 0 and happy(a - d2p13 + (d2p1
- 1)3 + 93·k + 93 + 53) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 23)
> 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 83 + 63)) end if;
#note the 89 will automatically work
end do; end do:

```

```

a := 396720
ktop := 544
406, 5, -1
541, 2, -1
544, 8, -1

```

(45)

```

> a := 396703; #final digits 00
ktop := iquo(a, 93);
for k from 0 to ktop do # k is the number of nines at the end of N1.
for d2p1 from 1 to 9 do
# d2p1 is the digit that precedes the k digits of zeros in the number ending with 00.
if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 73) > 0 and happy(a - d2p13 + (d2p1
- 1)3 + 93·k + 93 + 43) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 13)
> 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 83 + 83)) end if;
end do; end do:

```

```

a := 396703
ktop := 544
134, 1, -1
438, 3, -1
510, 6, -1
517, 3, -1
543, 3, -1

```

(46)

```

> a := 336782; #final digits 02
ktop := iquo(a, 93);
for k from 0 to ktop do # k is the number of nines at the end of N1.
for d2p1 from 1 to 9 do
# d2p1 is the digit that precedes the k digits of zeros in the number ending with 02.
if happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 93) > 0 and happy(a - d2p13 + (d2p1
- 1)3 + 93·k + 93 + 63) > 0 and happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 33)
> 0 then print(k, d2p1, happy(a - d2p13 + (d2p1 - 1)3 + 93·k + 93 + 03), happy(a
- d2p13 + (d2p1 - 1)3 + 93·k + 83 + 73)) end if;

```

end do; end do:

a := 336782
*k*_{top} := 461
82, 7, 4, -1
187, 9, -1, -1

(47)

>
>
>
for *a* **from** 75000 **to** 500000 **do**
 for *d*₁ **from** 0 **to** 9 **do**
 s := (1 - *a* - *d*₁) **mod** 3;
 for *d*₀ **from** *s* **to** 9 **by** 3 **do**
 if *happy*(*a* + *onestep*(*d*₁·10 + *d*₀)) > 0 **and** *happy*(*a* + *onestep*(*d*₁·10 + *d*₀ + 3)) > 0
 and *happy*(*a* + *onestep*(*d*₁·10 + *d*₀ + 6)) > 0 **and** *happy*(*a* + *onestep*(*d*₁·10 + *d*₀
 + 9)) > 0 **then** *print*(*a*, *d*₁, *d*₀, *happy*(*a* + *onestep*(*d*₁·10 + *d*₀ + 12)), *happy*(*a*
 + *onestep*(*d*₁·10 + *d*₀ + 15)), *happy*(*a* + *onestep*(*d*₁·10 + *d*₀ + 18))); **end if**;
 end do;
 end do;
end do;

76350, 8, 5, -1, -1, -1
76815, 6, 7, -1, -1, -1
76942, 7, 8, -1, 4, -1
77175, 6, 4, 4, -1, -1
77175, 6, 7, -1, -1, -1
77238, 6, 1, -1, 4, -1
77240, 8, 3, -1, 4, -1
77329, 5, 1, -1, -1, -1
77392, 4, 5, -1, -1, -1
77393, 4, 7, -1, -1, 4
77446, 2, 1, -1, 4, -1
77454, 0, 1, -1, -1, 4
77608, 4, 5, -1, -1, 4
77627, 5, 3, 4, -1, 6
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