

Strings of Consecutive CUBIC Happy Numbers

1 March 2008

15 Aug 2008

Here we use the cubes of the digits instead of the squares.

We need a procedure, given n , to find the minimal N such that $S(N) = n$. In or text explanations, we will denote this minimal N by $L(n)$.

```
> restart;  
> f := n → n^3; #in case we ever want to investigate the cube of the digits, etc.  
f := n → n3 (1)
```

```
> bs := 10;  
#this is the base, in case we ever want to investigate binary or ternary or any other base.  
bs := 10 (2)
```

```
> onestep := proc(n1)  
#this is what Dr. Grundman calls S_2(n1) and what we will simply call S below.  
local ans, n, d;  
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) (3)  
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)  
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

```

Given the values for $L(k)$ for all $k < n$, we will bootstrap ourselves to find the next value of $L(n)$. To do this, we try all possible final digits of $L(n)$, and take the best candidate. First, we need a procedure that will add the trial digit to the number and sort the digits.

```

> AddSortDigits := proc(a, d)
  local b, e, i;
  b := a;
  e := [ ];
  while b > 0 do e := [ b mod bs, op(e) ]; b := iquo(b - (b mod bs), bs); end do;
  e := [op(e), d];
  e := sort(e);
  b := 0;
  for i from 1 to nops(e) do
  b := b·bs + e[i];
  end do;
  b;
end;

```

```

AddSortDigits := proc(a, d)
  local b, e, i;
  b := a;
  e := [ ];
  while 0 < b do e := [ mod(b, bs), op(e) ]; b := iquo(b - (mod(b, bs)), bs) end do;
  e := [op(e), d];
  e := sort(e);
  b := 0;
  for i to nops(e) do b := b*bs + e[i] end do;
  b
end proc

```

```

> AddSortDigits(36436, 4)
                                     334466

```

Now we initialize our list of least values.

```

> A := [1, 11, 111, 1111, 11111, 111111, 1111111, 11111111, 2];
                                     A := [1, 11, 111, 1111, 11111, 111111, 1111111, 11111111, 2]

```

```

> for n from 9 to 26 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 2 do
  M := AddSortDigits(A[n - onestep(d)], d);
  if M < L then L := M; end if;
end do;

```

```

A := [op(A), L];
end do;
> A := [op(A), 3];
A := [1, 11, 111, 1111, 11111, 111111, 1111111, 2, 12, 112, 1112, 11112, 111112, 1111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 222, 1222, 11222, 3]

```

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>
> for n from 28 to 63 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 3 do
    M := AddSortDigits(A[n - onestep(d)], d);
    if M < L then L := M; end if;
  end do;
  A := [op(A), L];
end do;

```

```

> A := [op(A), 4];
A := [1, 11, 111, 1111, 11111, 111111, 1111111, 2, 12, 112, 1112, 11112, 111112, 1111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 222, 1222, 11222, 3, 13, 113, 1113, 11113, 2222, 12222, 112222, 23, 123, 1123, 11123, 111123, 22222, 122222, 1122222, 223, 1223, 11223, 111223, 1111223, 222222, 1222222, 11222222, 2223, 12223, 112223, 33, 133, 1133, 11133, 111133, 22223, 122223, 1122223, 233, 1233, 4]

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> for n from 65 to 124 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 4 do
    M := AddSortDigits(A[n - onestep(d)], d);
    if M < L then L := M; end if;
  end do;
  A := [op(A), L];
end do;

```

```

> A := [op(A), 5];
A := [1, 11, 111, 1111, 11111, 111111, 1111111, 2, 12, 112, 1112, 11112, 111112, 1111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 222, 1222, 11222, 3, 13, 113, 1113, 11113, 2222, 12222, 112222, 23, 123, 1123, 11123, 111123, 22222, 122222, 1122222, 223, 1223, 11223, 111223, 1111223, 222222, 1222222, 11222222, 2223, 12223, 112223, 33, 133, 1133, 11133, 111133, 22223, 122223, 1122223, 233, 1233, 4, 14, 114, 1114, 11114, 2233, 12233, 24, 124, 1124, 11124, 111124, 22233, 122233, 224, 333, 1333, 11333, 111333, 22233, 122233, 2224, 2333, 12333, 34, 134, 1134, 11134, 111134, 22224, 22333, 122333, 234, 1234, 11234, 111234, 1111234, 22224, 222333, 1222333, 2234, 3333, 13333, 113333, 1113333, 222224, 2222333, 12222333, 22234, 23333, 123333, 334, 1334, 11334, 111334, 1111334, 222234, 223333, 5]

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> for n from 126 to 215 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 5 do
    M := AddSortDigits(A[n - onestep(d)], d);

```

```

if  $M < L$  then  $L := M$ ; end if;
end do;
 $A := [op(A), L]$ ;
end do;

```

```

>  $A := [op(A), 6]$ ;

```

```

 $A := [1, 11, 111, 1111, 11111, 111111, 1111111, 11111111, 2, 12, 112, 1112, 11112, 111112, 1111112, 11111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 111111122, 222, 1222, 11222, 3, 13, 113, 1113, 11113, 2222, 12222, 112222, 23, 123, 1123, 11123, 111123, 22222, 122222, 1122222, 223, 1223, 11223, 111223, 1111223, 222222, 1222222, 11222222, 2223, 12223, 112223, 33, 133, 1133, 11133, 111133, 22223, 122223, 1122223, 233, 1233, 4, 14, 114, 1114, 11114, 111114, 2233, 12233, 24, 124, 1124, 11124, 111124, 1111124, 22233, 122233, 224, 333, 1333, 11333, 111333, 1111333, 222233, 1222233, 2224, 2333, 12333, 34, 134, 1134, 11134, 111134, 22224, 22333, 122333, 234, 1234, 11234, 111234, 1111234, 222224, 222333, 1222333, 2234, 3333, 13333, 113333, 1113333, 2222224, 2222333, 12222333, 22234, 23333, 123333, 334, 1334, 11334, 111334, 1111334, 222234, 223333, 5, 15, 115, 44, 144, 1144, 11144, 111144, 25, 125, 1125, 244, 1244, 11244, 111244, 1111244, 225, 1225, 11225, 2244, 3334, 13334, 113334, 1113334, 2225, 12225, 112225, 35, 135, 1135, 344, 1344, 11344, 111344, 1111344, 235, 1235, 11235, 2344, 12344, 112344, 1112344, 11112344, 2235, 12235, 112235, 22344, 33334, 133334, 1133334, 11133334, 22235, 122235, 1122235, 335, 1335, 11335, 3344, 13344, 113344, 1113344, 11113344, 2335, 12335, 45, 145, 1145, 444, 1444, 11444, 22335, 122335, 245, 1245, 11245, 2444, 12444, 112444, 222335, 1222335, 2245, 3335, 13335, 22444, 33344, 133344, 1133344, 11133344, 22245, 23335, 123335, 6]$ 

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> for  $n$  from 217 to 342 do
   $L := AddSortDigits(A[n - 1], 1)$ ;
  for  $d$  from 2 to 6 do
     $M := AddSortDigits(A[n - onestep(d)], d)$ ;
    if  $M < L$  then  $L := M$ ; end if;
  end do;
   $A := [op(A), L]$ ;
end do;

```

```

>  $A := [op(A), 7]$ ;

```

```

 $A := [1, 11, 111, 1111, 11111, 111111, 1111111, 11111111, 2, 12, 112, 1112, 11112, 111112, 1111112, 11111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 111111122, 222, 1222, 11222, 3, 13, 113, 1113, 11113, 2222, 12222, 112222, 23, 123, 1123, 11123, 111123, 22222, 122222, 1122222, 223, 1223, 11223, 111223, 1111223, 222222, 1222222, 11222222, 2223, 12223, 112223, 33, 133, 1133, 11133, 111133, 22223, 122223, 1122223, 233, 1233, 4, 14, 114, 1114, 11114, 111114, 2233, 12233, 24, 124, 1124, 11124, 111124, 1111124, 22233, 122233, 224, 333, 1333, 11333, 111333, 1111333, 222233, 1222233, 2224, 2333, 12333, 34, 134, 1134, 11134, 111134, 22224, 22333, 122333, 234, 1234, 11234, 111234, 1111234, 222224, 222333, 1222333, 2234, 3333, 13333, 113333, 1113333, 2222224, 2222333, 12222333, 22234, 23333, 123333, 334, 1334, 11334, 111334, 1111334, 222234, 223333, 5, 15, 115, 44, 144, 1144, 11144, 111144, 25, 125, 1125, 244, 1244, 11244, 111244, 1111244, 225, 1225, 11225, 2244, 3334, 13334, 113334, 1113334, 2225, 12225, 112225, 35, 135, 1135, 344, 1344, 11344, 111344, 1111344, 235, 1235, 11235,$ 

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2344, 12344, 112344, 1112344, 11112344, 2235, 12235, 112235, 22344, 33334, 133334, 1133334, 11133334, 22235, 122235, 1122235, 335, 1335, 11335, 3344, 13344, 113344, 1113344, 11113344, 2335, 12335, 45, 145, 1145, 444, 1444, 11444, 22335, 122335, 245, 1245, 11245, 2444, 12444, 112444, 222335, 1222335, 2245, 3335, 13335, 22444, 33344, 133344, 1133344, 11133344, 22245, 23335, 123335, 6, 16, 116, 1116, 11116, 111116, 223335, 1223335, 26, 126, 1126, 11126, 111126, 1111126, 2223335, 12223335, 226, 1226, 11226, 111226, 333344, 1333344, 11333344, 111333344, 2226, 12226, 112226, 36, 136, 1136, 11136, 111136, 22226, 122226, 55, 155, 1155, 445, 1445, 11445, 4444, 14444, 255, 1255, 11255, 2445, 12445, 112445, 24444, 124444, 2255, 12255, 112255, 22445, 336, 1336, 11336, 111336, 22255, 122255, 1122255, 355, 1355, 11355, 46, 146, 1146, 11146, 111146, 2355, 12355, 112355, 246, 1246, 11246, 111246, 1111246, 22355, 122355, 1122355, 2246, 3336, 13336, 113336, 1113336, 222355, 1222355, 11222355, 3355, 13355, 113355, 346, 1346, 11346, 111346, 1111346, 23355, 123355, 455, 1455, 11455, 4445, 14445, 114445, 44444, 144444, 2455, 12455, 33336, 24445, 124445, 1124445, 244444, 1244444, 22455, 33355, 133355, 224445, 3346, 13346, 113346, 1113346, 222455, 233355, 1233355, 56, 156, 7]

```
> for n from 344 to 511 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 7 do
    M := AddSortDigits(A[n - onestep(d)], d);
    if M < L then L := M; end if;
  end do;
  A := [op(A), L];
end do;
```

```
> A := [op(A), 8];
```

A := [1, 11, 111, 1111, 11111, 111111, 1111111, 2, 12, 112, 1112, 11112, 111112, 1111112, 11111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 111111122, 222, 1222, 11222, 3, 13, 113, 1113, 11113, 2222, 12222, 112222, 23, 123, 1123, 11123, 111123, 22222, 122222, 1122222, 223, 1223, 11223, 111223, 1111223, 222222, 1222222, 11222222, 2223, 12223, 112223, 33, 133, 1133, 11133, 111133, 22223, 122223, 1122223, 233, 1233, 4, 14, 114, 1114, 11114, 111114, 2233, 12233, 24, 124, 1124, 11124, 111124, 1111124, 22233, 122233, 224, 333, 1333, 11333, 111333, 1111333, 222233, 1222233, 2224, 2333, 12333, 34, 134, 1134, 11134, 111134, 22224, 22333, 122333, 234, 1234, 11234, 111234, 1111234, 222224, 222333, 1222333, 2234, 3333, 13333, 113333, 1113333, 2222224, 2222333, 12222333, 22234, 23333, 123333, 334, 1334, 11334, 111334, 1111334, 222234, 223333, 5, 15, 115, 44, 144, 1144, 11144, 111144, 25, 125, 1125, 244, 1244, 11244, 111244, 1111244, 225, 1225, 11225, 2244, 3334, 13334, 113334, 1113334, 2225, 12225, 112225, 35, 135, 1135, 344, 1344, 11344, 111344, 1111344, 235, 1235, 11235, 2344, 12344, 112344, 1112344, 11112344, 2235, 12235, 112235, 22344, 33334, 133334, 1133334, 11133334, 22235, 122235, 1122235, 335, 1335, 11335, 3344, 13344, 113344, 1113344, 11113344, 2335, 12335, 45, 145, 1145, 444, 1444, 11444, 22335, 122335, 245, 1245, 11245, 2444, 12444, 112444, 222335, 1222335, 2245, 3335, 13335, 22444, 33344, 133344, 1133344, 11133344, 22245, 23335, 123335, 6, 16, 116, 1116, 11116, 111116, 223335, 1223335, 26, 126, 1126, 11126, 111126, 1111126, 2223335, 12223335, 226, 1226,

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11226, 111226, 333344, 1333344, 11333344, 111333344, 2226, 12226, 112226, 36, 136, 1136, 11136, 111136, 22226, 122226, 55, 155, 1155, 445, 1445, 11445, 4444, 14444, 255, 1255, 11255, 2445, 12445, 112445, 24444, 124444, 2255, 12255, 112255, 22445, 336, 1336, 11336, 111336, 22255, 122255, 1122255, 355, 1355, 11355, 46, 146, 1146, 11146, 111146, 2355, 12355, 112355, 246, 1246, 11246, 111246, 1111246, 22355, 122355, 1122355, 2246, 3336, 13336, 113336, 1113336, 222355, 1222355, 11222355, 3355, 13355, 113355, 346, 1346, 11346, 111346, 1111346, 23355, 123355, 455, 1455, 11455, 4445, 14445, 114445, 44444, 144444, 2455, 12455, 33336, 24445, 124445, 1124445, 244444, 1244444, 22455, 33355, 133355, 224445, 3346, 13346, 113346, 1113346, 222455, 233355, 1233355, 56, 156, 7, 17, 117, 1117, 11117, 111117, 256, 1256, 27, 127, 1127, 11127, 111127, 1111127, 2256, 122256, 2227, 356, 1356, 37, 137, 1137, 11137, 111137, 555, 1555, 11555, 237, 1237, 11237, 44445, 144445, 2555, 12555, 112555, 2237, 12237, 112237, 244445, 1244445, 22555, 122555, 1122555, 22237, 3356, 13356, 337, 1337, 11337, 111337, 1111337, 3555, 13555, 113555, 456, 1456, 47, 147, 1147, 11147, 111147, 1111147, 2456, 12456, 247, 1247, 11247, 111247, 1111247, 11111247, 22456, 33356, 2247, 3337, 13337, 113337, 1113337, 11113337, 33555, 133555, 22247, 66, 166, 347, 1347, 11347, 111347, 1111347, 4555, 266, 1266, 2347, 12347, 112347, 444445, 1444445, 24555, 2266, 12266, 22347, 33337, 133337, 1133337, 11133337, 224555, 22266, 122266, 222347, 366, 1366, 3347, 13347, 113347, 222266, 1222266, 556, 1556, 57, 157, 1157, 447, 1447, 11447, 2556, 12556, 257, 1257, 11257, 2447, 12447, 112447, 22556, 122556, 2257, 12257, 3366, 13366, 33347, 133347, 222556, 1222556, 22257, 3556, 13556, 357, 466, 1466, 3447, 13447, 5555, 15555, 115555, 2357, 2466, 12466, 23447, 123447, 25555, 125555, 1125555, 22357, 8]

```

> for n from 513 to 728 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 8 do
    M := AddSortDigits(A[n - onestep(d)], d);
    if M < L then L := M; end if;
  end do;
  A := [op(A), L];
end do;

```

```

> A := [op(A), 9];

```

```

A := [1, 11, 111, 1111, 11111, 111111, 1111111, 2, 12, 112, 1112, 11112, 111112, 1111112,
11111112, 22, 122, 1122, 11122, 111122, 1111122, 11111122, 111111122, 222, 1222,
11222, 3, 13, 113, 1113, 11113, 2222, 12222, 112222, 23, 123, 1123, 11123, 111123,
22222, 122222, 1122222, 223, 1223, 11223, 111223, 1111223, 222222, 1222222,
11222222, 2223, 12223, 112223, 33, 133, 1133, 11133, 111133, 22223, 122223, 1122223,
233, 1233, 4, 14, 114, 1114, 11114, 2233, 12233, 24, 124, 1124, 11124, 111124,
1111124, 22233, 122233, 224, 333, 1333, 11333, 111333, 222233, 1222233,
2224, 2333, 12333, 34, 134, 1134, 11134, 111134, 22224, 22333, 122333, 234, 1234,
11234, 111234, 1111234, 22224, 222333, 1222333, 2234, 3333, 13333, 113333, 1113333,
222224, 2222333, 12222333, 22234, 23333, 123333, 334, 1334, 11334, 111334, 1111334,
222234, 223333, 5, 15, 115, 44, 144, 1144, 11144, 25, 125, 1125, 244, 1244,
11244, 111244, 1111244, 225, 1225, 11225, 2244, 3334, 13334, 113334, 1113334, 2225,

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12225, 112225, 35, 135, 1135, 344, 1344, 11344, 111344, 1111344, 235, 1235, 11235, 2344, 12344, 112344, 1112344, 11112344, 2235, 12235, 112235, 22344, 33334, 133334, 1133334, 11133334, 22235, 122235, 1122235, 335, 1335, 11335, 3344, 13344, 113344, 1113344, 11113344, 2335, 12335, 45, 145, 1145, 444, 1444, 11444, 22335, 122335, 245, 1245, 11245, 2444, 12444, 112444, 222335, 1222335, 2245, 3335, 13335, 22444, 33344, 133344, 1133344, 11133344, 22245, 23335, 123335, 6, 16, 116, 1116, 11116, 111116, 223335, 1223335, 26, 126, 1126, 11126, 111126, 1111126, 2223335, 12223335, 226, 1226, 11226, 111226, 333344, 1333344, 11333344, 111333344, 2226, 12226, 112226, 36, 136, 1136, 11136, 111136, 22226, 122226, 55, 155, 1155, 445, 1445, 11445, 4444, 14444, 255, 1255, 11255, 2445, 12445, 112445, 24444, 124444, 2255, 12255, 112255, 22445, 336, 1336, 11336, 111336, 22255, 122255, 1122255, 355, 1355, 11355, 46, 146, 1146, 11146, 111146, 2355, 12355, 112355, 246, 1246, 11246, 111246, 1111246, 22355, 122355, 1122355, 2246, 3336, 13336, 113336, 1113336, 222355, 1222355, 11222355, 3355, 13355, 113355, 346, 1346, 11346, 111346, 1111346, 23355, 123355, 455, 1455, 11455, 4445, 14445, 114445, 44444, 144444, 2455, 12455, 33336, 24445, 124445, 1124445, 244444, 1244444, 22455, 33355, 133355, 224445, 3346, 13346, 113346, 1113346, 222455, 233355, 1233355, 56, 156, 7, 17, 117, 1117, 11117, 111117, 256, 1256, 27, 127, 1127, 11127, 111127, 1111127, 2256, 12256, 227, 1227, 11227, 111227, 1111227, 22256, 122256, 2227, 356, 1356, 37, 137, 1137, 11137, 111137, 555, 1555, 11555, 237, 1237, 11237, 44445, 144445, 2555, 12555, 112555, 2237, 12237, 112237, 244445, 1244445, 22555, 122555, 1122555, 22237, 3356, 13356, 337, 1337, 11337, 111337, 1111337, 3555, 13555, 113555, 456, 1456, 47, 147, 1147, 11147, 111147, 1111147, 2456, 12456, 247, 1247, 11247, 111247, 1111247, 11111247, 22456, 33356, 2247, 3337, 13337, 113337, 1113337, 11113337, 33555, 133555, 22247, 66, 166, 347, 1347, 11347, 111347, 1111347, 4555, 266, 1266, 2347, 12347, 112347, 444445, 1444445, 24555, 2266, 12266, 22347, 33337, 133337, 1133337, 11133337, 224555, 22266, 122266, 222347, 366, 1366, 3347, 13347, 113347, 222266, 1222266, 556, 1556, 57, 157, 1157, 447, 1447, 11447, 2556, 12556, 257, 1257, 11257, 2447, 12447, 112447, 22556, 122556, 2257, 12257, 3366, 13366, 33347, 133347, 222556, 1222556, 22257, 3556, 13556, 357, 466, 1466, 3447, 13447, 5555, 15555, 115555, 2357, 2466, 12466, 23447, 123447, 25555, 125555, 1125555, 22357, 8, 18, 118, 1118, 11118, 111118, 1111118, 222357, 28, 128, 1128, 3466, 13466, 33447, 133447, 35555, 228, 1228, 4556, 14556, 457, 1457, 11457, 4447, 2228, 12228, 24556, 38, 138, 1138, 11138, 24447, 22228, 122228, 224556, 238, 1238, 11238, 33466, 133466, 222228, 1222228, 335555, 2238, 12238, 566, 1566, 67, 167, 1167, 11167, 22238, 45555, 2566, 338, 267, 1267, 11267, 111267, 222238, 245555, 22566, 2338, 2267, 48, 148, 1148, 11148, 111148, 222566, 22338, 22267, 248, 1248, 367, 1367, 11367, 111367, 222338, 5556, 2248, 557, 1557, 11557, 4457, 14457, 114457, 25556, 22248, 2557, 12557, 348, 1348, 11348, 111348, 225556, 222248, 22557, 122557, 2348, 12348, 3367, 13367, 113367, 1113367, 222557, 35556, 22348, 3557, 4566, 14566, 467, 1467, 11467, 111467, 222348, 23557, 24566, 3348, 2467, 12467, 112467, 1112467, 2222348, 223557, 58, 158, 1158, 448, 1448, 11448, 111448, 1111448, 258, 1258, 11258, 666, 1666, 3467, 13467, 113467, 2258, 12258, 45556, 2666, 4557, 14557, 114557, 44457, 22258, 122258, 245556, 358, 1358, 11358,

3448, 13448, 113448, 1113448, 2245556, 2358, 12358, 112358, 3666, 13666, 33467, 133467, 1133467, 22358, 122358, 5566, 15566, 567, 1567, 77, 177, 1177, 11177, 25566, 3358, 2567, 12567, 277, 1277, 11277, 111277, 225566, 23358, 22567, 458, 1458, 11458, 4448, 14448, 114448, 223358, 222567, 2458, 12458, 3567, 4666, 377, 1377, 11377, 55556, 22458, 5557, 15557, 24666, 2377, 12377, 112377, 255556, 222458, 25557, 125557, 68, 9]

To find how far we need to go we use our maximal length single-digit numbers 1111111222222333344444555566677777888888888 which we see below is the most of each digit we can string together.

> onestep(1111111222222333344444555566677777888888888) (15)
8297

```
> for n from 730 to 8300 do
  L := AddSortDigits(A[n - 1], 1);
  for d from 2 to 9 do
    M := AddSortDigits(A[n - onestep(d)], d);
    if M < L then L := M; end if;
  end do;
  A := [op(A), L];
end do;
```

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- > *onestep*(6668889999) (17)
- 5100
- > *onestep*(888888888); *A*[%]; (18)
- 4608
888888888
- > *onestep*(8888888888); *A*[%]; (19)
- 5120
1229999999
- > *onestep*(777777); *A*[%]; (20)
- 2058
777777
- > *onestep*(7777777); *A*[%]; (21)
- 2401
666889
- > *onestep*(666); *A*[%]; (22)
- 648
666
- > *onestep*(6666); *A*[%]; (22)
- 864

```

1278 (23)
> onestep(5555); A[%];
500
5555 (24)
> onestep(55555); A[%];
625
11467 (25)
> onestep(44444); A[%];
320
44444 (26)
> onestep(444444); A[%];
384
12555 (27)
> onestep(3333); A[%];
108
3333 (28)
> onestep(33333); A[%];
135
1125 (29)
> onestep(222222); A[%];
48
222222 (30)
> onestep(2222222); A[%];
56
1133 (31)

```

So we could never possibly hope that a string without the digit 9 can have $S(N)$ bigger than $S(N)$ with $N = 1111111222222333344444555566677777888888888$ than with more digits

We now find the biggest number with a given digit.

```

> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 9 then print(n, A[n]); fini := true; end if;
  end do;
      fini := false
      4609, 1888888888 (32)
>
> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 8 then print(n, A[n]); fini := true; end if;
  end do;
      fini := false
      2183, 5777777 (33)
>
> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 7 then print(n, A[n]); fini := true; end if;
  end do;

```

```

                                fini := false
                                932, 555566

```

(34)

```

> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 6 then print(n, A[n]); fini := true; end if;
  end do;

```

```

                                fini := false
                                572, 245555

```

(35)

```

> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 5 then print(n, A[n]); fini := true; end if;
  end do;

```

```

                                fini := false
                                329, 1244444

```

(36)

```

> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 4 then print(n, A[n]); fini := true; end if;
  end do;

```

```

                                fini := false
                                124, 223333

```

(37)

```

> fini := false;
  for n from 8300 to 10 by -1 while fini = false do
  if A[n] mod 10 < 3 then print(n, A[n]); fini := true; end if;
  end do;

```

```

                                fini := false
                                50, 11222222

```

(38)

```
>
```

```
>
```

In particular, if $n > 4609$, then $L(n)$ must have the digit 9 in it.

```

> iquo(4609, 93)
                                6

```

(39)

```

> 7·93;
                                5103

```

(40)

We now use this to find the least $L(n)$ for the values of interest in our main program. 19750 is for four in a row.

```

> minimalN := proc(n)
  local q, r, k, ans;
  global lowS;;
  if n < 5104 then ans := A[n];
  else
  q := iquo(n, 93, 'r');
  ans := A[n - (q - 7)·93]·10q-7 + (10q-7 - 1);
  end if;
  ans;
end;

```

(41)

