From last time

Describe in detail what happens when the following ARM program is obeyed. At each step, clearly describe the movement of information (both numbers and instructions) between the memory (RAM) and the processor, and how the values in the memory and in registers R0, R1, R2 and R15 (PC) change. Assume that the program starts at memory location 0. (5 marks)

```
B   d
a  DEFW 23
b  DEFW 45
c  DEFW 10
d  LDR  R0, a
    STR  R0, c
    LDR  R1, b
    ADD  R2, R1, R0
    STR  R2, a
    SVC 2; terminate program
```
Answer

PC=0:  **fetch instruction**: PC (0) → RAM; copy contents of word 0 (“B d”) → processor; increment PC by 4
**execute**: unconditional branch to d: 16 → PC

PC=16: **fetch** (as above) “LDR R0, a” from word 16; PC+4
**execute**: address a (4) → RAM, copy memory word 4 (23) → register R0 in processor: R0=23

PC=20: **fetch** “STR R0, c” from word 20; PC+4
**execute**: address c (12) & copy of R0 (23) → RAM, contents of memory word 12 changed from 10 to 23: c=23

PC=24: **fetch** “LDR R1, b” from word 24; PC+4
**execute**: address b (8) → RAM, copy word 8 (45) → R1 in processor: R1=45

PC=28: **fetch** “ADD R2, R1, R0” from word 28; PC+4
**execute**: add copies of R1 (45) & R0 (23), result to R2: R2=68

PC=32: **fetch** “STR R2, a” from word 32; PC+4
**execute**: address a (4) & copy of R2 (68) → RAM, word 12 changed from 23 to 68: a=68

PC=36: **fetch** “SVC 2” from word 36; PC+4
**execute**: stop the program
Question

Our student registration numbers used to be a year number (e.g. “009” for 2009) followed by 5 more decimal digits.

What was the maximum number of students that we could register in one year?

e.g. 009XXXXX = individual “XXXXX” from 2009

00000 to 99999 = $10^5$ different individuals in any one year

How many bits are needed to number this many students?

$2^{17} \geq 10^5 > 2^{16}$, so 17 bits

How many bits are needed to count the current Human population of Earth?

$2^{33} > 7.2 \times 10^9 > 2^{32}$, so 33 bits

In general to represent values in $[0, MAX]$, we need $\lceil \log_2 MAX \rceil$ bits
“FAT” filesystems use 3 characters to show type of file (e.g. .txt, .htm, .mp3). Each character can be a digit or a letter (ignoring case).

How many different file types can be encoded?

\[ 36^3 = 46656 \]
allowing trailing spaces \[ 36^3 + 36^2 + 36 = 47988 \]

How many bits would be needed to record this information?

\[ 2^{16} = 65536, 2^{15} = 32768, \text{ so } 16 \text{ bits} \]

As each character is a byte, how much memory is wasted?

\[ 3 \times 8 - 16 = 8 \text{ bits wasted} \]
Question

Without using a calculator, convert the decimal number $47_{10}$ to binary.

$47 \div 2 = 23r1$
$23 \div 2 = 11r1$
$11 \div 2 = 5r1$
$5 \div 2 = 1r1$
$2 \div 2 = 1r0$
$1 \div 2 = 0r1$

so $47_{10} = 101111_2$
Question

Without using a calculator, convert the binary number $101111_2$ to octal and hexadecimal.

\[ = 101 \ 111_2 = 57_8 \]

\[ = 0010 \ 1111_2 = 2F_{16} \]
Question

Without using a calculator, convert the hexadecimal number 47 to octal and binary,

\[ 47_{16} = 100 \ 0111_2 \]
\[ = 1000111_2 \]
\[ = 1 \ 000 \ 111_2 = 107_8 \]

and then to decimal.

\[ 1 \times 2^6 + 0 \times 2^5 + 0 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 1 \times 2 + 1 \]

or \[ 4 \times 16 + 7 \]

or \[ 1 \times 8^2 + 0 \times 8 + 7 \]

\[ = 71_{10} \]
Question

In Britain, new car registration numbers are of the form “LLDD LLL”
– L = any capital letter except “I”,
– D = any decimal digit (“DD” changes every 6 months)

What is the maximum number of cars that can be registered in each 6 months?
AA?? AAA to ZZ?? ZZZ (but no Is) = 25^5 = 9,765,625

How many bits would be needed to number this many cars?
2^{24} \geq 9,765,625 > 2^{23}, so 24 bits
(roughly 16 million : 10 million : 8 million)