Binary, denary and hexadecimal

Computer systems (Paper 1) · revision notes

Converting positive whole numbers between denary (base 10), binary (base 2) and hexadecimal (base 16), within the J277 range: denary 0 to 255, binary up to 8 bits and hexadecimal 00 to FF. These are quick, reliable marks on Paper 1 once you have practised the methods by hand.

Key facts

- 8-bit place values: 128 64 32 16 8 4 2 1
- Hex digits: 0–9, A = 10, B = 11, C = 12, D = 13, E = 14, F = 15
- Denary → hex: ÷ 16; the whole number is the first digit, the remainder is the second
- FF = 255 = 11111111; 00 = 0 = 00000000
- 8 bits: 0 to 255 (256 values); n bits: 2^n values
- Hex → denary: first digit × 16 + second digit
- 1 hex digit = 4 bits (a nibble); nibble place values 8 4 2 1
- MSB = left-most bit; LSB = right-most bit

Notes

Binary and denary

- Denary is base 10 (digits 0 to 9); binary is base 2 (only 0 and 1).
- 8-bit place values: `128 64 32 16 8 4 2 1`.
- The left-most bit is the **most significant bit** (MSB); the right-most bit is the **least significant bit** (LSB).
- Binary → denary: add the place values of the columns holding a 1. E.g. `01011010` = 64 + 16 + 8 + 2 = 90.
- Denary → binary: start at 128. If the number is at least the place value, write 1 and subtract; otherwise write 0. Move right and repeat. E.g. 150 = 128 + 16 + 4 + 2 = `10010110`.

128	64	32	16	8	4	2	1
1	0	0	**1**	0	**1**	**1**	0

128 + 16 + 4 + 2 = 150

150 in binary: a 1 goes under each place value used

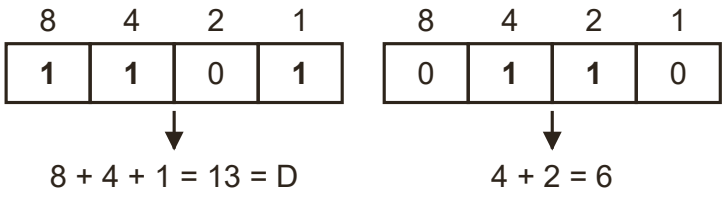
- 8 bits can hold 256 different values, from 0 (`00000000`) to 255 (`11111111`). In general, n bits give 2^n different values. Grade 7+ only

Hexadecimal

- Hexadecimal (base 16) uses the digits 0 to 9 and then A = 10, B = 11, C = 12, D = 13, E = 14, F = 15.
- A 2-digit hex number has place values 16 and 1. The largest is FF = 15 × 16 + 15 = 255.
- Hex → denary: first digit × 16 + second digit. E.g. 7C = 7 × 16 + 12 = 112 + 12 = 124.
- Denary → hex: divide by 16. The whole number of 16s is the first digit and the remainder is the second. E.g. 203 ÷ 16 = 12 remainder 11, so 203 = CB.

Binary and hexadecimal

- One hex digit represents exactly 4 bits (a nibble), because 4 bits give 2^4 = 16 patterns.
- Binary → hex: split the bits into nibbles from the right and convert each one using `8 4 2 1`. E.g. `1101 0110` → 13 and 6 → D6.



11010110 = D6

Split into nibbles, convert each with 8 4 2 1, then write each as one hex digit

- Hex → binary: write each digit as 4 bits. E.g. 3E → `0011` and `1110` → `00111110`.
- If a binary number has fewer than 8 bits, add 0s on the **left**, never on the right.
- Hex is used because it is shorter than binary and easier for people to read, remember and type, so fewer mistakes are made. It also converts easily to and from binary.

How to answer each type of question

M = method mark, A = answer mark, B = a mark on its own.

Convert between binary and denary 1 mark each **Grade 4**

1. Write the place values 128 to 1 above the bits.
2. Binary to denary: add the values above each 1.
3. Denary to binary: subtract the largest place value you can, working left to right, and give all 8 bits.
4. Check by converting your answer back.

Example. (a) Convert the binary number 10100011 into denary. [1]
(b) Convert the denary number 77 into 8-bit binary. [1]

Model answer.

(a) 128 + 32 + 2 + 1 = 163 (1)
(b) 77 = 64 + 8 + 4 + 1, so 01001101 (1)

Convert between hexadecimal and binary

1 to 2 marks | Grade 5

1. Hex to binary: write each hex digit as a 4-bit nibble.
2. Binary to hex: split into nibbles from the right, convert each using 8 4 2 1, and write 10 to 15 as A to F.

Example. (a) Convert the hexadecimal number A7 into 8-bit binary. [2]
(b) Convert the binary number 00111011 into hexadecimal. [1]

Model answer.

(a) A = 1010 (1) and 7 = 0111 (1), so 10100111

(b) 0011 = 3 and 1011 = 11 = B, so 3B (1)

Convert between denary and hexadecimal, showing working

2 marks each | Grade 6

1. Hex to denary: multiply the first digit by 16, then add the second digit.
2. Denary to hex: divide by 16; write the quotient and the remainder as hex digits.
3. Or go via binary if you find that easier.

Example. (a) Convert the hexadecimal number 5E into denary. Show your working. [2]
(b) Convert the denary number 180 into hexadecimal. Show your working. [2]

Model answer.

(a) 5 × 16 = 80 and E = 14 (1); 80 + 14 = 94 (1)

(b) 180 ÷ 16 = 11 remainder 4 (1); 11 = B, so B4 (1)

Explain why hexadecimal is used

2 marks | Grade 6

1. Give a reason about length: one hex digit replaces four bits.
2. Give a reason about people: easier to read, remember and type, so fewer errors.
3. Remember that the computer still stores the value in binary.

Example. A programmer views the contents of memory in hexadecimal rather than binary. Explain **two** reasons why. [2]

Model answer. Hexadecimal is shorter because one hex digit represents four bits, so values are quicker to read and write (1). It is easier for people to read and remember, so fewer mistakes are made when copying values (1). Also accept: it is easy to convert between hexadecimal and binary.

Don’t lose marks

- Writing the bits in reverse order, with the least significant bit on the left.
- Giving fewer than 8 bits when 8-bit binary is asked for. Add leading zeros.
- Grouping bits into nibbles from the left when there are fewer than 8 bits. Always group from the right.

- Writing 1011 as '11' in hex instead of B.
- In hex to denary, multiplying the second digit by 16 instead of the first.

More tips

Memory tricks

- Hex letters: A is 10, then count up: A10, B11, C12, D13, E14, F15.
- Denary to hex the easy way: go via binary. 180 → 1011 0100 → B4.
- Quick checks: odd denary numbers end in 1 in binary; any number of 128 or more starts with 1 in 8 bits.
- Learn the 16 nibbles (0000 = 0 up to 1111 = F) and hex conversions become instant.

Exam technique

- Write the place values (128 … 1) on the paper before converting: it takes seconds and prevents slips.
- Show your working (place values, the ÷ 16 step): 2-mark conversions often give a method mark.
- Check each answer by converting it back the other way.
- Paper 1 is non-calculator, so practise conversions by hand until they are automatic.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Convert 8-bit binary to denary**
Add the place values (128, 64, 32, 16, 8, 4, 2, 1) of every column that holds a 1.

Grade 4 — **Convert denary to 8-bit binary**
Work from 128 downwards, putting a 1 in each column whose value you can subtract.

Grade 4 — **Identify the most and least significant bits**
The most significant bit is the left-most bit (worth 128 in 8 bits); the least significant bit is the right-most (worth 1).

Grade 5 — **Convert between binary and hexadecimal**
Split the 8 bits into two nibbles; each nibble is one hex digit from 0 to F.

Grade 6 — **Convert between denary and hexadecimal**
Hex to denary: first digit × 16 + second digit; denary to hex: divide by 16 and use the remainder.

Grade 6 — **Explain why hexadecimal is used**
It is shorter and easier for people to read and write than binary, so fewer mistakes are made, and it converts easily.

Grade 7 — **Reason about ranges and bit patterns**
E.g. n bits give 2^n values, odd numbers end in 1, and why each hex digit matches exactly four bits.

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