Grade 9 Computing

Unit 1 · How a Computer Really Works

ANSWER KEY · FOR TEACHERS

Full marks 30

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. half adder
2. latch
3. program counter
4. stored-program computer
5. assembly language
6. cache
7. interrupt
8. system call

Each carries 0.5 mark. **K · 4**

2 Label the diagram

1. Control unit (CU)
2. address bus
3. data bus
4. Arithmetic logic unit (ALU)

Each carries 0.5 mark. **K · 2**

3 Multiple choice

i. **b. AND** **U · 1**

The carry is 1 only when both bits are 1 (1 + 1 = 10), which is AND. The sum is XOR: 1 when the bits differ. OR would wrongly give a sum of 1 for 1 + 1.

ii. **b. sum 0, carry 1** **A · 1**

1 + 0 + 1 = 2, which is 10 in binary: write 0 (sum), carry 1.

iii. **c. The register keeps only 8 bits, 44, unless the program checks for the overflow.** **A · 1**

300 needs 9 bits. The carry out of the 8th adder has nowhere to go, so the register keeps 300 − 256 = 44. The ALU sets an overflow flag, but nothing happens unless the program checks it.

iv. **b. DRAM** **K · 1**

DRAM keeps each bit as a charge in a tiny capacitor, which leaks, so it must be refreshed. SRAM holds bits in latches; ROM and flash keep their data with no power at all.

v. **b. Apps run in user mode, where instructions that touch the hardware are refused; they must ask the kernel with a system call.** **U · 1**

Only the kernel, in kernel mode, works the hardware. An app asks it with a system call, so the operating system can check the app is allowed, keep files from being mixed up, and stop a harmful app from wiping someone else's data.

4 What does it print?

MARKING SCHEME **U · 3**

- ✓ Four lines, in the order 0 0, 0 1, 1 0, 1 1 (the outer loop is a).
- ✓ The carry 1 only for 1 1, and the sum 1 only for 0 1 and 1 0.
- ✓ A half adder (it adds two bits: 1 + 1 = 10).

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5 Adding with full adders

ANSWER A · 3

Column	A	B	Carry in	Sum	Carry out
1s	1	0	0	1	0
2s	1	1	0	0	1
4s	0	1	1	0	1
8s	1	0	1	0	1

The adder gives **0001**, which is 1. But 11 + 6 = 17, which needs 5 bits (10001): the carry out of the 8s column has nowhere to go. That is an **overflow**: 17 − 16 = 1.

MARKING SCHEME

- ✓ The 1s and 2s columns right: sum 1, carry 0; sum 0, carry 1.
- ✓ The 4s and 8s columns right, each with its carry in from the column on its right: sum 0, carry 1 both times.
- ✓ The 4 bits 0001 are wrong (11 + 6 = 17): the last carry out is lost, an overflow.

6 Trace the program

ANSWER A · 4

Instruction carried out	PC after	ACC after	Output
LOAD 14	1	6	
SUB 15	2	3	
OUT	3	3	3
JUMPZ 5	4	3	
JUMP 1	1	3	
SUB 15	2	0	
OUT	3	0	0
JUMPZ 5	5	0	
HALT	6	0	

MARKING SCHEME

- ✓ SUB 15 then OUT: the ACC 3, and 3 shown.
- ✓ The first JUMPZ 5 doesn't jump (the ACC is 3, not 0), and JUMP 1 puts 1 in the PC: the loop goes round again.
- ✓ The second time round, SUB makes the ACC 0 and OUT shows 0.
- ✓ JUMPZ 5 now jumps (PC 5), and HALT stops the program. Output 3, 0.

7 Short answers

a. **MARKING SCHEME** U · 1

- ✓ 0111 0101: 0111 for JUMPZ, then 5 in 4 bits.

b. **MARKING SCHEME** U · 2

- ✓ A compiler translates the whole program into machine code before it runs (and it can then be run again and again); an interpreter translates and runs it a line at a time, every time it runs.
- ✓ Python is usually run by an interpreter.

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8 Long answer

ANSWER U · 4

1. **Fetch:** the address in the program counter is sent along the address bus, with a "read" signal on the control bus. Memory sends the instruction at that address along the data bus into the instruction register. The program counter goes up by one, so it points to the next instruction.
2. **Decode:** the control unit works out what the instruction means: the operation and the address or register it uses.
3. **Execute:** the instruction is carried out: the ALU calculates, data is copied between memory and registers (using the buses again), or, for a jump, a new address is put in the program counter.

Then the cycle starts again with the next fetch, billions of times a second. Between instructions the processor checks for interrupts.

MARKING SCHEME

- ✓ Fetch: the address in the program counter goes out on the address bus, with a read on the control bus; the instruction comes back on the data bus into the instruction register.
- ✓ The program counter goes up by one, so it points to the next instruction (a jump puts a new address in it instead).
- ✓ Decode: the control unit works out what the instruction means: the operation, and the address or register it uses.
- ✓ Execute: the instruction is carried out (the ALU calculates, data is copied, or the PC is changed); then the cycle starts again.

9 Think

ANSWER HA · 2

The processor can't run a program straight from secondary storage: it reaches only primary memory by address, so a program must be copied into RAM to run. Storage is also far slower: an SSD takes about 0.1 ms to answer, RAM about 100 ns, a thousand times quicker. But RAM costs much more for each byte, and it forgets everything when the power goes off, so the apps, photos and files must be kept in storage, which keeps them.

MARKING SCHEME

- ✓ The processor reaches only primary memory by address (it can't run from storage), and storage is far slower, so programs are copied into RAM to run.
- ✓ RAM costs much more for each byte, and forgets its data when the power goes off; storage is cheaper and keeps the files.

10 Activity: Find a limit of your calculator

(not marked)

WHAT STUDENTS SHOULD FIND

1. Many calculators show 1 again, because they keep more digits than they show, or round; some show 0.9999999. Either way, 1 ÷ 3 can't be kept exactly in a fixed number of digits.
2. The answer in a short form with E (an exponent), or an error: the calculator keeps only so many digits.
3. With an 8-digit screen, after 27 twos ($2^{27} = 134{,}217{,}728$ has 9 digits); with 10 digits, after 34 twos. Some phone calculators keep far more digits and go much further.

Each is the limit of a fixed number of digits (bits, inside), like the 8-bit ACC that turned 50 × 7 into 94.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	7	12	9	2	30

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