1. The table below shows the standard AQA assembly language instruction set that should be used to answer part (a) and part (b)

Standard AQA assembly language instruction set

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B<condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.

`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a `#` or an `R`:

- `#` – use the decimal value specified after the `#`, eg `#25` means use the decimal value 25
- `Rm` – use the value stored in register `m`, eg `R6` means use the value stored in register 6

The available general purpose registers that the programmer can use are numbered 0–12

(a) Shade **one** lozenge to show which of the assembly instructions in the figure below uses immediate addressing.

	Instruction	Immediate Addressing
A	`LDR R3, 42`	⬭
B	`MOV R3, #42`	⬭
C	`STR R3, 101`	⬭
D	`SUB R3, R2, R1`	⬭

(1)

(b) A computer program is required that will multiply the value stored in X by 2 if it is less than 50 and leave it unchanged if it is 50 or more.

The algorithm for this task can be written in pseudocode as:

```
IF X < 50 THEN
   X ← X * 2
ENDIF
```

Write an assembly language program using the AQA assembly language instruction set shown in the table above to carry out this task.

At the start, the value of X is stored in memory location 101

(4)

(Total 5 marks)

2. **This table is included so that you can answer parts (a) and (b).**

Standard AQA assembly language instruction set

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B <condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.

HALT	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label the identifier of the label is placed after the branch instruction.

Interpretation of <operand2>

<operand2> can be interpreted in two different ways, depending on whether the first character is a # or an R:

- # – use the decimal value specified after the #, eg #25 means use the decimal value 25
- Rm – use the value stored in register m, eg R6 means use the value stored in register 6

The available general-purpose registers that the programmer can use are numbered 0–12

The figure below shows an assembly language program that has been written using the AQA Assembly Language Instruction Set, which is given in the table above.

```
   LDR R0, 120
   LDR R1, 121
   MOV R3, #0
loop:
   CMP R1, #0
   BEQ exit
   AND R2, R1, #1
   CMP R2, #0
   BEQ skip
   ADD R3, R3, R0
skip:
   LSL R0, R0, #1
   LSR R1, R1, #1
   B loop
exit:
   STR R3, 122
   HALT
```

(a) State the name of the addressing mode used in the instruction ADD R3, R3, R0

_____

(1)

(b) Memory location 120 contains the value 23 and memory location 121 contains the value 5.

Complete the trace table to show how the contents of the memory locations and registers change when the program in above code is executed.

Memory locations			**Registers**			
120	121	122	R0	R1	R2	R3
23	5					

(5)

(c) State the purpose of the program in the code above.

_____

_____

_____

(1)

(d) The program in the code above has been written using assembly language.

State **two** reasons why the programmer may have chosen to write this program in assembly language rather than in a high-level programming language.

Reason 1 _____

_____

_____

Reason 2 _____

_____

_____

(2)

(e) The program in the code above will be translated into machine code.

Explain the relationship between an assembly language instruction and a machine code instruction.

_____

_____

_____

(1)

(Total 10 marks)

3. The table below shows the standard AQA assembly language instruction set. This should be used to answer question parts **(a)** and **(b)**.

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B<condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a # or an R:

- `#` – use the decimal value specified after the `#`, eg `#25` means use the decimal value 25.
- `Rm` – use the value stored in register `m`, eg `R6` means use the value stored in register 6.

The available general purpose registers that the programmer can use are numbered 0 to 12.

(a) **Figure 1** shows an incomplete assembly language program. The intended purpose of the code is to count from 1 to 10 inclusive, writing the values to memory location 17, which is used to control a motor.

Complete the code in **Figure 1**. You may not need to use all four lines for your solution and you should not write more than one instruction per line.

Figure 1

```
            MOV R0, #1
startloop:

            STR R0, 17

            _____________________________

            _____________________________

            _____________________________

            _____________________________

endloop:

            HALT
```

(4)

(b) `R1` contains the decimal value 7. What value will be contained in `R1` after the instruction below is executed?

```
LSL R1, R1, #2
```

_____

(1)

(Total 5 marks)

4. **Standard AQA assembly language instruction set**. This should be used to answer question part (a).

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B<condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.

`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label, the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a # or an `R`:

- # - Use the decimal value specified after the #, e.g. #`25` means use the decimal value 25
- `Rm` – Use the value stored in register `m`, e.g. `R6` means use the value stored in register 6

The available general purpose registers that the programmer can use are numbered 0 to 12

The figure below shows an algorithm, written in pseudo-code, that is used to multiply two box variables `W` and `X` together. The resulting answer is stored in variable `Y`. It can be assumed that both `W` and `X` are positive integers. Z is a temporary variable. The operation DIV performs integer division.

Line numbers are included but are not part of the algorithm.

```
1 W ← 9
2 x ← 12
3 Y ← 0
4 REPEAT
5    z ← W LOGICAL BITWISE AND 1
6    IF Z = 1 THEN
7       Y ← Y + X
8    END IF
9    W ← W DIV 2
10    X ← X * 2
11    UNTIL W = 0
```

Write a sequence of assembly language instructions that perform multiplication using the same method shown in the algorithm above.

Assume that registers 0, 1, 2 and 3 are used to store the values represented by variables `W`, `X`, `Y` and `Z` accordingly.

Some lines, including those equivalent to line numbers 1 to 5 in the algorithm above, have been completed for you.

```
                MOV R0, #9
                MOV R1, #12
                MOV R2, #0
startloop:      AND R3, R0, #1

                ____________________________________

                ____________________________________

                ____________________________________

      jump:

                ____________________________________

                ____________________________________

                ____________________________________

                ____________________________________

                ____________________________________

                B startloop
    endloop:
```

(Total 7 marks)

5.

Standard AQA assembly language instruction set

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B <condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a # or an R:

- `#` – use the decimal value specified after the `#`, eg `#25` means use the decimal value 25
- `Rm` – use the value stored in register `m`, eg `R6` means use the value stored in register 6

The available general-purpose registers that the programmer can use are numbered 0–12

The Vernam cipher encrypts a plaintext character by performing a logical operation between a character in the plaintext and part of the key.

Write an assembly language program, **using the AQA assembly language instruction set** shown in the table above, to encrypt a plaintext character using this method.

You should assume that:

- the character code of the plaintext character to be encrypted is stored in memory location 101
- the part of the key to use to encrypt the character is stored in memory location 102

The encrypted ciphertext character should be stored in memory location 103

(Total 3 marks)

6. **This table is included so that you can answer part (a).**

Standard AQA assembly language instruction set

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B <condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label, the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a # or an R:

- `#` – use the decimal value specified after the `#`, eg `#25` means use the decimal value 25
- `Rm` – use the value stored in register `m`, eg `R6` means use the value stored in register 6

The available general-purpose registers that the programmer can use are numbered 0–12

The code below shows an assembly language program which has been written using the AQA assembly language instruction set. The instruction set is explained in the table above.

```
   CMP R2, #0
   BEQ exit
   MOV R0, #0
   MOV R3, #1
moveleft:
   LSL R2, R2, #1
   LSL R3, R3, #1
   CMP R2, R1
   BLT moveleft
   BEQ mainloop
   LSR R2, R2, #1
   LSR R3, R3, #1
mainloop:
   CMP R1, R2
   BLT skip
   ADD R0, R0, R3
   SUB R1, R1, R2
skip:
   AND R4, R3, #1
   CMP R4, #1
   BEQ skipshiftR2
   LSR R2, R2, #1
skipshiftR2:
   LSR R3, R3, #1
   CMP R3, #0
   BNE mainloop
exit:
   HALT
```

The program takes its input values from registers `R1` and `R2` and stores its output in registers `R0` and `R1`

(a) Complete the trace table below to show the results of executing the program in the code above when the initial values in registers `R1` and `R2` are 34 and 6

Each register can hold a 16-bit value.

You may find it easier to understand the operation of the program if you write the contents of the registers out in both binary and decimal.

You may not need to use all the rows in the table.

R0	R1	R2	R3	R4
	100010 (34)	110 (6)		

(6)

(b) The initial values for the program (its inputs) are stored in `R1` and `R2` and the final values stored in `R0` and `R1` are its outputs.

By considering the inputs and the outputs in your trace table for part (a), describe the purpose of the program.

_____

_____

_____

_____

_____

_____

(2)

(Total 8 marks)

7. **Table 1** shows the standard AQA assembly language instruction set that should be used to answer the question below.

Table 1 – standard AQA assembly language instruction set

`LDR Rd, <memory ref>`	Load the value stored in the memory location specified by `<memory ref>` into register `d`.
`STR Rd, <memory ref>`	Store the value that is in register `d` into the memory location specified by `<memory ref>`.
`ADD Rd, Rn, <operand2>`	Add the value specified in `<operand2>` to the value in register `n` and store the result in register `d`.
`SUB Rd, Rn, <operand2>`	Subtract the value specified by `<operand2>` from the value in register `n` and store the result in register `d`.
`MOV Rd, <operand2>`	Copy the value specified by `<operand2>` into register `d`.
`CMP Rn, <operand2>`	Compare the value stored in register `n` with the value specified by `<operand2>`.
`B <label>`	Always branch to the instruction at position `<label>` in the program.
`B<condition> <label>`	Branch to the instruction at position `<label>` if the last comparison met the criterion specified by `<condition>`. Possible values for `<condition>` and their meanings are: `EQ`: equal to `NE`: not equal to `GT`: greater than `LT`: less than
`AND Rd, Rn, <operand2>`	Perform a bitwise logical AND operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`ORR Rd, Rn, <operand2>`	Perform a bitwise logical OR operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`EOR Rd, Rn, <operand2>`	Perform a bitwise logical XOR (exclusive or) operation between the value in register `n` and the value specified by `<operand2>` and store the result in register `d`.
`MVN Rd, <operand2>`	Perform a bitwise logical NOT operation on the value specified by `<operand2>` and store the result in register `d`.
`LSL Rd, Rn, <operand2>`	Logically shift left the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`LSR Rd, Rn, <operand2>`	Logically shift right the value stored in register `n` by the number of bits specified by `<operand2>` and store the result in register `d`.
`HALT`	Stops the execution of the program.

Labels: A label is placed in the code by writing an identifier followed by a colon (:). To refer to a label the identifier of the label is placed after the branch instruction.

Interpretation of `<operand2>`

`<operand2>` can be interpreted in two different ways, depending on whether the first character is a `#` or an `R`:

- `#` – use the decimal value specified after the `#`, eg `#25` means use the decimal value 25
- `Rm` – use the value stored in register `m`, eg `R6` means use the value stored in register 6

The available general purpose registers that the programmer can use are numbered 0–12

Write an assembly language program to encrypt a single character using the Caesar cipher. The character to be encrypted is represented using a character set consisting of 26 characters with character codes 0–25. The output of the process should be the character code of the encrypted character.

The assembly language instruction set that you should use to write the program is listed in **Table 1**.

Table 2 shows the character codes and the characters they represent.

Table 2

Code	Character
0	A
1	B
2	C
3	D
4	E
5	F
6	G
7	H
8	I

Code	Character
9	J
10	K
11	L
12	M
13	N
14	O
15	P
16	Q
17	R

Code	Character
18	S
19	T
20	U
21	V
22	W
23	X
24	Y
25	Z

- Memory location 100 contains the character code to be encrypted, which is in the range 0–25
- Memory location 101 contains an integer key to be used for encryption, which is in the range 0–25
- The program should store the character code of the encrypted character in memory location 102

(Total 4 marks)