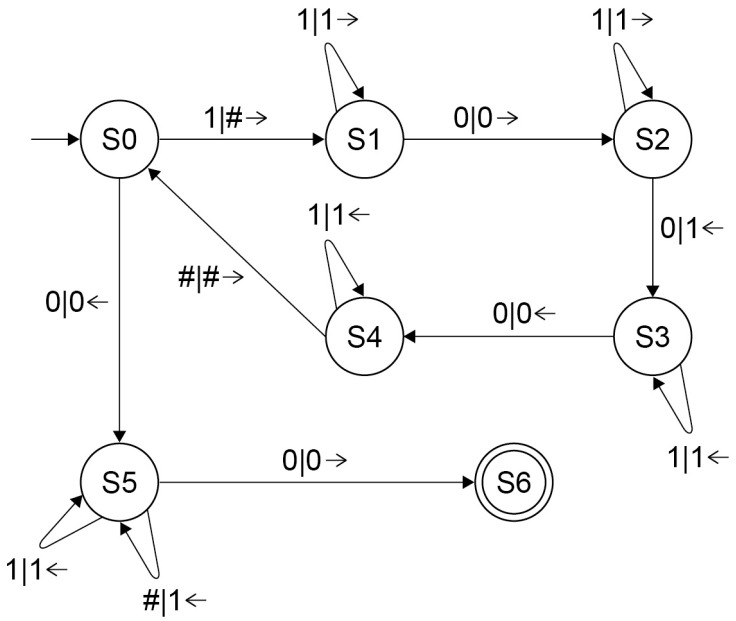
0 1 **Figure 2** shows the transition function (represented as a state transition diagram) and part of the tape for a Turing machine designed to complete a task. The current position of the read/write head is indicated by the * symbol.

Figure 2



...	0	1*	1	0	0	0	0	...

The label 1|#→ on the transition from S0 to S1 means if the machine is in state S0 and a 1 is read from the tape then a # should be written to the tape and then the read/write head moved one cell to the right.

0 1 . 1 After four steps of the computation have been completed, the current state, the tape contents and the position of the read/write head are:

Tape

...	0	#	1	0*	1	0	0	...

Current state

S3

Complete the unshaded cells of **Table 1** to show the result of tracing the computation of this Turing machine, from step five onwards. Show the contents of the tape, the current position of the read/write head and the current state as the input symbols are processed. Step four has been repeated at the start of the trace.

Table 1

Tape								Current state
...	0	#	1	0*	1	0	0	...	S3
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	
...								...	

Copy the contents of the unshaded cells in **Table 1** into the table in your Electronic Answer Document.

[5 marks]

0 1 . 2 What is the purpose of the Turing machine shown in **Figure 2**?

[1 mark]

0 1 . 3 What is the purpose of the transition from S5 to S6 in the Turing machine in **Figure 2**?

[1 mark]

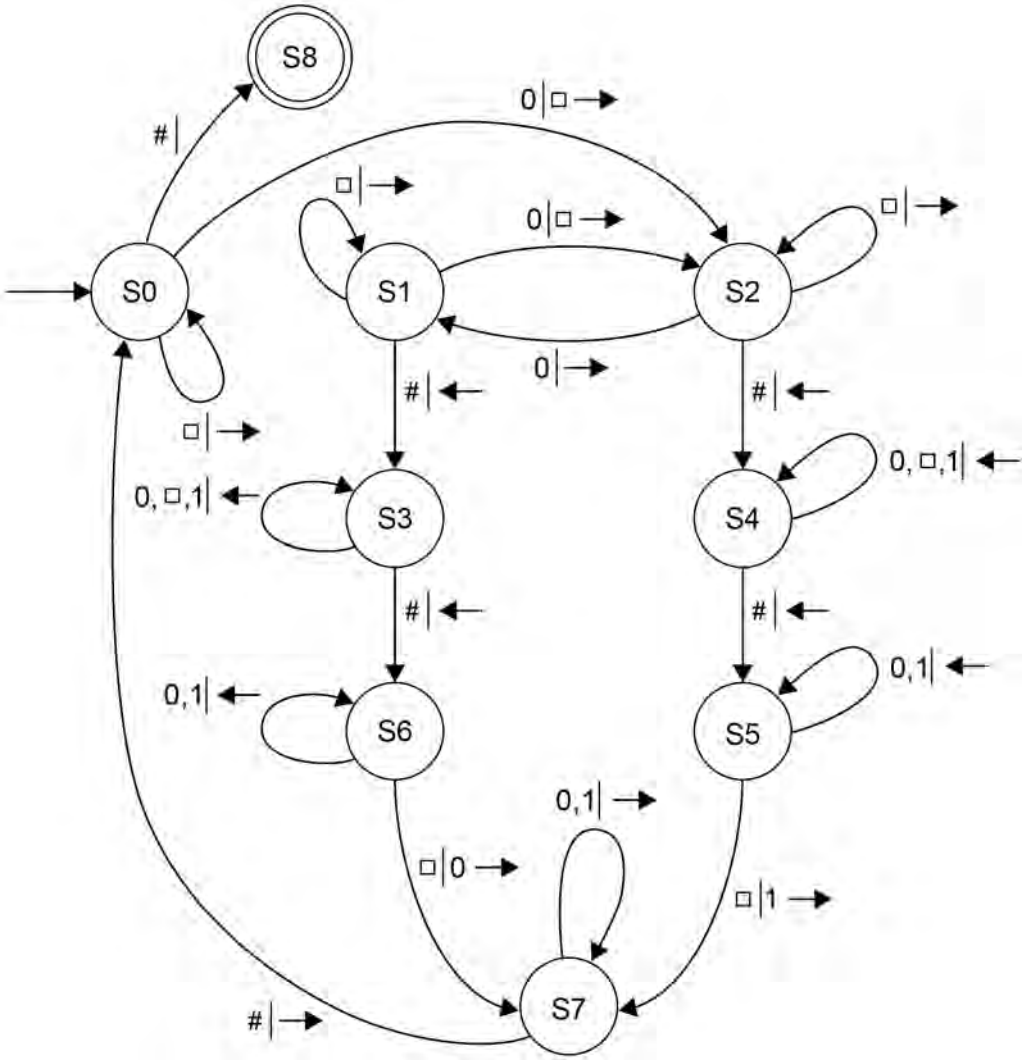
0 1 . 4 Explain what a Universal Turing machine is.

[2 marks]

0 2 **Figure 5** shows the transition function (represented as a state transition diagram) and part of the tape for a Turing machine designed to count the number of zeros between two # symbols on the tape.

The current position of the read/write head is indicated by the * symbol.

Figure 5



…	#	0*	0	0	#	…

The □ symbol is used to denote an empty cell on the tape.

The label $\square|0\rightarrow$ on the transition from S6 to S7 means if the machine is in state S6 and a □ is read from the tape, then a 0 should be written to the tape and then the read/write head is moved one cell to the right.

The label $0,\square,1|\leftarrow$ on the transition from S3 to S3 means if the machine is in state S3 and a □, a 0 or a 1 is read from the tape, then the read/write head is moved one cell to the left; the contents of the tape are not changed.

0 2 . 1 Complete the unshaded cells of **Table 3** to show the result of tracing the computation of this Turing machine **for the first 20 steps only**.

Show the contents of the tape, the current position of the read/write head and the current state as the input is processed. The top row of the table shows the initial state, the initial position of the read/write head and the starting contents of the tape.

Table 3

Tape										Current state
…			#	0*	0	0	#		…	S0
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	
…									…	

Copy the contents of the unshaded cells in **Table 3** into the table in your Electronic Answer Document.

[5 marks]

0 2 . 2 Describe **two** circumstances when the transition function for this Turing machine will **not** correctly count the number of zeros between two # symbols on the tape.

You should assume that:

- the read/write head starts immediately to the right of a cell containing a #
- there is a cell containing a # symbol somewhere on the tape to the right of the read/write head's initial position
- there are exactly two # symbols on the tape.

[2 marks]

0 2 . 3 Explain what a Universal Turing machine is.

[2 marks]

0 2 . 4 State **one** reason why there are some problems that no real computer can solve that the Universal Turing Machine could solve.

[1 mark]