

# 1. (3.8) Give Implementation level detail descriptions of Turing machines that decide the following languages over the alphabet $\{0,1\}$

## 1.1. a. $\{w \mid w \text{ contains an equal number of 0's and 1's}\}$

$M =$  On input  $\langle p \rangle$ , a binary string:

0 . Move cursor to end of string, right until empty char, and place symbol ?z

1 . goto step 2

2 . Move cursor to beginning of string and goto step 4

3. Move cursor to the right

4. When ?1 is read, mark it with ?c

Move cursor to the right

When ?w is read, change it to ?z

Move cursor to the left

When ?c is read, change it to ?x and goto step 5

When ?0 is read, mark it with ?c

Move cursor to the right

When ?w is read, change it to ?z

Move cursor to the left

When ?c is read, change it to ?x and goto step 6

1

When ?x is read goto step 3

When ?z is read, reject

When ?w is read, accept

5 . Move the cursor to the right

if ?1 is read, change it to ?c

if ?z is read, change it to ?w

Move cursor to the left

When c is read, mark it with a ?x and goto 2

6. Move the cursor to the right

if ?0 is read, change it to ?c

if ?z is read, change it to ?w

Move cursor to the left

When ?c is read, mark it with a ?x and goto 2"

## 1.2. b. $\{w \mid w \text{ contains twice as many 0s as 1s}\}$

$M =$  On input  $\langle p \rangle$ , a binary string:

0 . Move cursor to end of string, right until empty char, and place symbol ?z

1 . goto step 2

2 . Move cursor to beginning of string and goto step 4

3. Move cursor to the right

4. When ?1 is read, mark it with ?c

Move cursor to the right

If ?w is read, change it to ?z

Move cursor to the left

If ?c is read, change it to ?x and goto step 5

When ?0 is read, mark it with ?c

Move cursor to the right

If ?w is read, change it to ?z

Move cursor to the left

If ?c is read, change it to ?x and goto step 6

When ?x is read goto step 3

When ?z is read, reject

When ?w is read, accept

5 . Move the cursor to the right

When ?0 is read, change it to ?x

Move the cursor to the right

When ?1 is read, change it to ?c

When ?z is read, change it to ?w

Move the cursor to the left

When ?c is read change it to ?x, goto step 2

6. Move the cursor to the right

When ?0 is read, change it to ?c

Move the cursor to the right

When ?0 is read, change it to ?c

When ?z is read, change it to ?w

Move the cursor to the left

When ?c is read change it to ?x, goto step 2

2

**1.3. c.**  $\{w \mid w \text{ does not contain twice as many 0s as 1s}\}$

$M =$  On input  $\langle p \rangle$ , a binary string:

0 . Move cursor to end of string, right until empty char, and place symbol ?z

1 . goto step 2

2 . Move cursor to beginning of string and goto step 4

3. Move cursor to the right

4. When ?1 is read, mark it with ?c

Move cursor to the right

If ?z is read, goto 5

If ?w is read, change it to ?z

Move cursor to the left

If ?c is read, change it to ?x and goto step 6

When ?0 is read, mark it with ?c

Move cursor to the right

If ?z is read, goto 5

If ?w is read, change it to ?z

Move cursor to the left

If ?c is read, change it to ?x and goto step 7

When ?x is read goto step 3

5 When ?z is read, accept

When ?w is read, reject

6 . Move the cursor to the right

When ?0 is read, change it to ?x

Move the cursor to the right

When ?1 is read, change it to ?c

When ?z is read, change it to ?w

Move the cursor to the left

When ?c is read change it to ?x, goto step 2

7. Move the cursor to the right

When ?0 is read, change it to ?c

Move the cursor to the right

When ?0 is read, change it to ?c

When ?z is read, change it to ?w

Move the cursor to the left

When ?c is read change it to ?x, goto step 2