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Pumping lemma:

For a regular language A with the pumping length P , if S is any string of A with minimum length of P , then the string S can be divided into 3 pieces x , y and z represented as $S = xyz$ should satisfy the following conditions:

- for each
- $|y| > 0$, and
- $|xy| \leq P$

a.

Consider the Language $L = \{0^n 1^m 0^n \mid m, n \geq 0\}$.

Assume that L is regular language and a string $S = 0^P 1 0^P$. Divide the string into three pieces x , y and z . So, $S = 0^P 1 0^P = xyz$ where, P is the pumping length.

Assume that $x = 0^{P-K}$, $y = 0^K$ and $z = 1 0^P$ (where $K > 0$)

Now $xy^0 z = 0^{P-K} (0^K)^0 1 0^P$

$= 0^{P-K} 1 0^P \notin L \quad [\because y^0 = \epsilon]$

The String $xy^0 z$ does not belong to L because $P-K < P$.

So, the assumption that L is regular is a contradiction. Thus, by using pumping lemma it is proved that L is not regular.

b.

Consider the Language $L = \{0^m 1^n \mid m \neq n\}$.

Assume that L is regular language and string $S = 0^P 1^{P+P!}$. Divide the string into three pieces x , y and z . So, $S = 0^P 1^{P+P!} = xyz \in L$ and $|S| \geq P$ where, P is the pumping length.

[Note: $P!$ is divisible by all integers from 1 to P , where $P! = P \times (P-1) \times (P-2) \times \dots \times 1$.]

Assume that $x = 0^a$, $y = 0^b$ and $z = 0^c 1^{P+P!}$, where $b \geq 1$ and $a+b+c = P$.

Now take string $s' = xy^{i+1} z$, where $i = \frac{P!}{b}$.

Then $y^i = 0^{P!}$ so $y^{i+1} = 0^{b+P!}$, and

So $xyz = 0^{a+b+c+P!} 1^{P+P!}$.

That gives $xyz = 0^{P+P!} 1^{P+P!} \notin L$, a contradiction.

Here, $m = P + P!$, $n = P + P!$ and $m = n$. This is a contradiction to the assumption because $m \neq n$. Thus, by using pumping lemma it is proved L is not regular.

c.

Consider the Language $L = \{w \mid w \in \{0,1\}^* \text{ is not a palindrome}\}$.

Assume that L is regular language.

The compliment of the language L is $\bar{L} = \{w \mid w \in \{0,1\}^* \text{ is palindrome}\}$ is also regular.

Assume a string $S = 0^P 1 0^P$. Divide the string into three pieces x , y and z . So, $S = 0^P 1 0^P = xyz \in L$ where, P is the pumping length.

Assume that $x = 0^{P-K}$, $y = 0^K$ and $z = 1 0^P$ where $K > 0$

Now $xy^0 z = 0^{P-K} (0^K)^0 1 0^P$

$= 0^{P-K} 1 0^P \notin L \quad [\because y^0 = \epsilon]$

The String xy^0z is not same from forward and backward direction because $P-K < P$.

So, the string xy^0z does not belong to \bar{L} . So, the assumption is a contradiction.

Thus, by using pumping lemma it is proved L is not regular.

d.

Consider the Language $L = \{wtw \mid w, t \in \{0,1\}^+\}$.

Assume that L is regular language.

Assume a string $S = 0^p 1 0^p$. Divide the string into three pieces x , y and z . So, $S = 0^p 1 0^p = xyz \in L$ where, P is the pumping length.

Assume that $x = 0^{P-K}$, $y = 0^K$ and $z = 10^P$ where $K > 0$

Now $xy^0z = 0^{P-K} (0^K)^0 10^P$

$= 0^{P-K} 10^P \notin L \quad [\because y^0 = \epsilon]$

The String xy^0z does not belong to L because $P-K < P$ and not of the form wtw as in L .

So, the assumption is a contradiction. Thus, by using pumping lemma it is proved L is not regular.