GATE-CS.51

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Question: Consider the following recurrence:

$$f(1) = 1; \tag{1}$$
$$f(2n) = 2f(n) - 1, \text{ for } n \geq 1; \tag{2}$$
$$f(2n+1) = 2f(n) + 1, \text{ for } n \geq 1. \tag{3}$$

Then, which of thefollowing is/are **TRUE?**
(A) $f(2^n - 1) = 2^n - 1$
(B) $f(2^n) = 1$
(C) $f(5 \cdot 2^n) = 2^{n+1} + 1$
(D) $f(2^n + 1) = 2^n + 1$
[GATE-CS.51 2022]
Solution:
(A)
let $x(2^k - 1) = 2^k - 1$ for any $k \geq 1$,

$$x(2^{k+1} - 1) = x(2(2^k - 1) + 1) \tag{4}$$

From (3),

$$= 2x(2^k - 1) + 1 \tag{5}$$
$$= 2(2^k - 1) + 1 \tag{6}$$
$$= 2^{k+1} - 1 \tag{7}$$

From (1),(7)

$$x(2 - 1) = 2 - 1 \ (k = 0) \tag{8}$$
$$= 1 \tag{9}$$

Hence $x(2^n - 1) = 2^n - 1$ for $n \geq 1$
So statement A is TRUE

(B)
Let $x(2^k) = 1$ for any $k \geq 0$

$$x(2^{k+1}) = x(2 \cdot 2^k) \tag{10}$$

From (2)

$$= 2x(2^k) - 1 \tag{11}$$
$$= 2 - 1 \tag{12}$$
$$= 1 \tag{13}$$

From (11),(2)

$$x(2) = 2x(1) - 1 \ (k = 0) \tag{14}$$
$$= 2 - 1 \tag{15}$$
$$= 1 \tag{16}$$

Hence $x(2^n) = 1$ for every $n \geq 0$ value.
So statement B is TRUE.

(C)
Let,$x(5 \cdot 2^k) = 2^{k+1} + 1$ be true for any $k \geq 0$,

$$x(5 \cdot 2^{k+1}) = x(2(5 \cdot 2^k)) \tag{17}$$

From (2)

$$= 2x(5 \cdot 2^k) - 1 \tag{18}$$
$$= 2(2^{k+1} + 1) - 1 \tag{19}$$
$$= 2^{k+2} + 1 \tag{20}$$

From (20)

$$x(5) = 2^1 + 1 \ (k = -1) \tag{21}$$
$$= 3 \tag{22}$$

Proof:-

$$x(5) = x(2 \cdot 2 + 1) \tag{23}$$

From (3),(16)

$$= 2x(2) + 1 \tag{24}$$
$$= 3 \tag{25}$$

Hence $x(5.2^n) = 2^{n+1} + 1$ for $n \geq 1$
So statement C is TRUE.

(D)

$$x(2^n + 1) = x(2 \cdot 2^{n-1} + 1) \tag{26}$$

From (3),(16)

$$= 2x(2^{n-1}) + 1 \tag{27}$$
$$= 2 + 1 \tag{28}$$
$$= 3 \tag{29}$$

Hence statement D is FALSE.

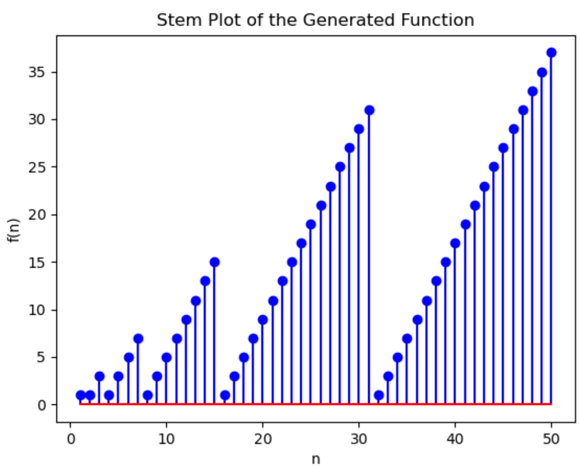

Fig. 1. plot of $x(n)$