Q2. Choosing window size $\Rightarrow 2^K - 1$, allows the system to distinguish if the data frames are received correctly and RR is a cummulative acknowledgment or if the data frames were damaged and receiving station is repeating its previous RR.

Eg Assume a 3 bit sequence no.
Sender sends frame 0 and gets back an RR
then sender sends frames 1, 2, 3, 4, 5, 6, 7, 0 and gets another RR
↳ Need to distinguish b/w correct acknowledgment or data loss.

Q3. Max. window size $= 2^{k-1}$
↳ This prevents packet from being misidentified. If window is more than ~~the sequence number~~ 2^{k-1} the sender may send fresh packets that the receiver interprets as retransmissions if ACK is missing.

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Q4 $\eta = \dfrac{dat}{dat + 2 \times prop}$

Given $\eta = 0.5$, Bit Rate = 4kbps

Propogation delay = 20ms

$$0.5 = \frac{dat}{dat + 2 \times 2 \times 10^{-2}}$$

$$0.5\, dat + 2 \times 10^{-2} = dat$$

$$\boxed{dat = 40 \times 10^{-3} s}$$

$$dat = \frac{\text{min. frame size}}{\text{bit rate}}$$

$$\text{min. frame size} = dat * \text{bit rate}$$

$$= 40 \times 10^{-3} * 4 \times 10^{3}$$

$$= 160 \text{ bits} \quad (\text{Ans})$$

Lower bound is 160 bits

Q5 Given: one character of 4 bits

Bit error probability $= 10^{-3}$

↳ independent in each bit

(a) Probability of no error = P(no error in 1st bit) * P(no error in 2nd bit) * P(no error in 3rd bit) * P(no error in 4th bit)

$$= (1 - 10^{-3})^4 \quad \{\text{independent}\}$$

$$= 0.996$$

(b) From the law of sum of probabilities from an exhaustive set of events is 1

P(No error) + P(atleast 1 error) = 1

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$$P(\text{atleast 1 error}) = 1 - P(\text{no error})$$
$$= 1 - 0.996$$
$$= 0.004$$

(c) we now add one parity bit

↓

2 cases can occur : (1) parity bit remains as it is

(2) parity bit flips due to error

(1) Parity bit remains as it is

↳ error undetected when flips of even no. of bits occur

$$P' = (1-10^{-3})\left[{}^4C_2 (10^{-3})^2 (1-10^{-3})^2 + {}^4C_4 (10^{-3})^4 \right]$$

$(1-10^{-3})$: parity bit unchanged

${}^4C_2 (10^{-3})^2 (1-10^{-3})^2$: 2 bit flips

${}^4C_4 (10^{-3})^4$: 4 bit flips

2 flips + 4 flips : even flips

(2) Parity bit changes / flips due to error

↳ undetected error with odd no. of bit flips

$$P'' = (10^{-3})\left[{}^4C_1 (10^{-3})(1-10^{-3})^3 + {}^4C_3 (10^{-3})^3 (1-10^{-3}) \right]$$

(10^{-3}) : parity bit flips

${}^4C_1 (10^{-3})(1-10^{-3})^3$: 1 bit flip

${}^4C_3 (10^{-3})^3 (1-10^{-3})$: 3 bit flip

$$\text{Ans} = P' + P''$$
$$= 9.97 \times 10^{-6} \quad \text{(Ans)}$$

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Q6

```
                 10110110
110011 ) 11100011 00000
         110011
         ------
         010111
         000000
         ------
          101111
          110011
          ------
           111000
           110011
           ------
            010110
            000000
            ------
             101100
             110011
             ------
              111110
              110011
              ------
               011010
               000000
               ------
                11010
```

11100011	11010
Dataword	Remainder

CRC value = 11010

Q1 (a) $P(x) = x^4 + x + 1$ → bit form = 10011

Bits to be encoded ⇒ 100100110110000

$x^{14} + x^{11} + x^8 + x^7 + x^5 + x^4$

```
                1000101010100
        ___________________________
1011   ) 100100110110000
         10011
         -----
          00010
          00000
          -----
           000101
           000000
           ------
            01011
            00000
            -----
             10110
             10011
             -----
              01011
              00000
              -----
               10111
               10011
               -----
                01000
                00000
                -----
                 10000
                 10011
                 -----
                  00110
                  00000
                  -----
                   01100
                   00000
                   -----
                    1100
```

CRC value ⇒ 1100

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(b) Error Pattern : 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0

Code word : 1 0 0 1 0 0 1 1 0 1 1 1 1 0 0

Received : 0 0 0 1 1 0 1 1 0 1 1 1 1 0 0 (1 bit flip at pos ⇒ 1 & 5)

```
                0 0 0 1 1 0 0 1 1 1 0
          ------------------------------
1 0 0 1 1 ) 0 0 0 1 1 0 1 1 0 1 1 1 1 0 0
            0 0 0 0 0
            -----------
              0 0 1 1 0
              0 0 0 0 0
              -----------
                0 1 1 0 1
                0 0 0 0 0
                -----------
                  1 1 0 1 1
                  1 0 0 1 1
                  -----------
                    1 0 0 0 0
                    1 0 0 1 1
                    -----------
                      0 0 1 1 1
                      0 0 0 0 0
                      -----------
                        1 1 1 1 1
                        1 0 0 1 1
                        -----------
                          1 1 0 0 1
                          1 0 0 1 1
                          -----------
                            1 1 0 0 1
                            1 0 0 1 1
                            -----------
                              1 1 0 0 1
                              1 0 0 1 1
                              -----------
                                1 0 1 0 0
                                1 0 0 1 1
                                -----------
                                  0 1 1 1 0
                                  0 0 0 0 0
                                  -----------
                                    1 1 1 0   → Non-zero
```

error is detected

Scanned with CamScanner

(c) Error Pattern : 1001 1000 000 000 0

Codeword : 1 0 0 1 0 0 1 1 0 1 1 1 1 0 0

Received : 0 0 0 0 1 0 1 1 0 1 1 1 1 0 0

```
              0 0 0 0 1 0 1 0 1 0 0
       ____________________________
10011 ) 0 0 0 0 1 0 1 1 0 1 1 1 1 0 0
        0 0 0 0 0
        ---------
          0 0 0 1 0
          0 0 0 0 0
          ---------
            0 0 1 0 1
            0 0 0 0 0
            ---------
              0 1 0 1 1
              0 0 0 0 0
              ---------
                1 0 1 1 0
                1 0 0 1 1
                ---------
                  0 1 0 1 1
                  0 0 0 0 0
                  ---------
                    1 0 1 1 1
                    1 0 0 1 1
                    ---------
                      0 1 0 0 1
                      0 0 0 0 0
                      ---------
                        1 0 0 1 1
                        1 0 0 1 1
                        ---------
                          0 0 0 0 0
                          0 0 0 0 0
                          ---------
                            0 0 0 0 0
                            0 0 0 0 0
                            ---------
                              0 0 0 0  → zero
```

errors not detected

CS425: Computer Networks
Assignment 4
Moksh Shukla 180433

Q1.

The code is attached to generate n bit CRC pattern. The code is written in python3 and can be simply run from the terminal by calling the script as "***python3 working directory/Q1.py"***
The code attached solves all the given parts in the question.

Sample output from the code is given below.

Input message: 1000111100
Sent CRC Frame: 1000111100011001
Error Pattern: 0010000100000010
Received CRC Frame: 1010110100011011
Received Frame Status: Reject