Problem-2:

Construct a combination of four Linear Congruential Generators to form a Combined linear congruential generator (CLCG) with the parameters for the four LCGs as:

$$a_1 = 8003;\ m_1 = 2^{64};\ c_1 = 0$$
$$a_2 = 8005;\ m_2 = 2^{32};\ c_2 = 0$$
$$a_3 = 8083;\ m_3 = 2^{16};\ c_3 = 0$$
$$a_4 = 8085;\ m_4 = 2^{8};\ c_4 = 0$$

The system will arbitrarily choose a generated random number from its list and input it to the Hangman Game (which is shown here) and predict the number by guessing its digits (from 0 - 9) one at a time and the game continues.

At last, show that the datas obtained from the CLCG satisfy the Kolmogorov-Smirnov Test for Normality and hence discuss your CLCG.

(The reason we are taking these parameter values are described properly in the report)

Solution-2:

we need to notice that the values of $c_1 = c_2 = c_3 = c_4 = 0$.

In [4]:

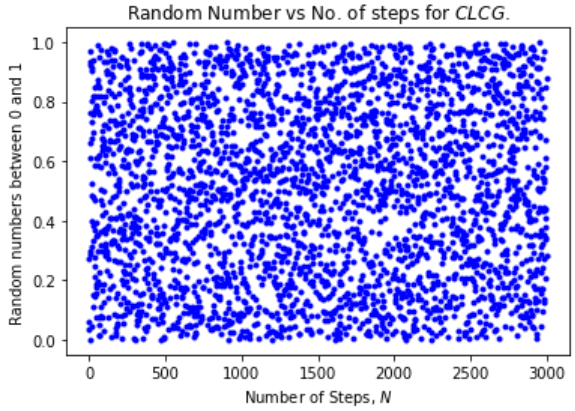
```
from pylab import show
import random
import matplotlib.pyplot as plt

k = 4; N = 3000          #defining the value of N and no. of LCGs (k=4).
#setting the parameters for the 4 LCGs.
a1 = 8003; m1 = 2**64; c1 = 0; x1 = random.randint(1, m1-1)
a2 = 8005; m2 = 2**32; c2 = 0; x2 = random.randint(1, m2-1)
a3 = 8083; m3 = 2**16; c3 = 0; x3 = random.randint(1, m3-1)
a4 = 8085; m4 = 2**8; c4 = 0; x4 = random.randint(1, m4-1)
results_1 = []; results_2 = []; results_3 = []; results_4 = []  #blank list for containing the values of Random numbers.
yval = []; rval = []
for i in range(N):           #performing the algorithm.
    x1 = (a1*x1+c1)%m1
    x2 = (a2*x2+c2)%m2
    x3 = (a3*x3+c3)%m3
    x4 = (a4*x4+c4)%m4
    results_1.append(x1)        #addding the results.
    results_2.append(x2)
    results_3.append(x3)
    results_4.append(x4)
    #solving the CLCG equation for the both.
    Y = (x1 - x2 + x3 - x4)%m1
    yval.append(Y)
    #calculating the random number between 0 and 1.
    if Y > 0:
        r = Y/m1
    elif Y < 0:
        r = Y/m1 + 1
    else:
        r = (m1-1)/m1
    rval.append(r)
print('A random number generated by the CLCG is:', Y)
print('Similarly, a random number between 0 and 1 generated by the CLCG is:', r)
plt.plot(rval,'.b', label = "clcg2")     #plotting r vs N.
plt.title("Random Number vs No. of steps for $CLCG$.")
plt.xlabel("Number of Steps, $N$")
plt.ylabel("Random numbers between 0 and 1")
plt.show()
################################
# GAME OF HANGMAN using the RNG#
################################
print('Ok, now let us play a game of Hangman. The number you will get will be random.')
name2 = [str(i) for i in yval]          #converting the random numbers in the list to str.
a = random.randint(0,len(yval))       #choosing the random number.
m = name2[a]; Y = []                 #choosing the indices.
X = [char for char in m]
for i in range(len(m)):
    Y.append(" ? ")          #choosing the number length and starting the game.
CHANCES = int(len(m)*3/5)   #counting the number of chances.
while CHANCES > 0:
    q = " "
    for j in range(len(Y)):     #for chances greater than 0.
        q += Y[j]
    print(q)
```

```
    print("This random number has "+str(len(Y))+" digits.")     #displaying the necessary info.
    print("You have "+str(CHANCES)+" chances left to guess it correctly.")
    print("(type 'skip' to skip) ")
    answer = input("Guess a digit from 0 - 9 of the number.").upper()  #taking the input from the player.
    if(answer in X):
        print("Wow, it's a correct guess!!!")
        for i in range(len(X)):         #checking for the answer in the number.
            if X[i] == answer:
                Y[i] = answer
                if " ? " not in Y:                 #when we have predicted all the digits.
                    print("Congratulations, You won! The random number was " + m + ".")
                    CHANCES = 0        #for chances == 0.
    elif answer == "SKIP":                #for skipping the game.
        CHANCES = 0
        print("Sorry to see you go, The random number was "+ m + ".")
    else:                                          #for the final part of the game in case of wrong answers.
        CHANCES -= 1
        print("Wrong guess! Try again.")
        if CHANCES == 0:
            print("So, Sorry. You lost the game. The random number was "+ m +".")

show()
```

```
A random number generated by the CLCG is: 16172260832451435169
Similarly, a random number between 0 and 1 generated by the CLCG is: 0.8767000164273039
```




```
Ok, now let us play a game of Hangman. The number you will get will be random.
  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?
This random number has 19 digits.
You have 11 chances left to guess it correctly.
(type 'skip' to skip)
Wow, it's a correct guess!!!
 1 ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ?  ? 1
This random number has 19 digits.
You have 11 chances left to guess it correctly.
(type 'skip' to skip)
Wow, it's a correct guess!!!
```

```
 1 ?  ?  ?  ?  ?  ?  ?  ?  ?  ? 4 ?  ?  ?  ?  ? 1
This random number has 19 digits.
You have 11 chances left to guess it correctly.
(type 'skip' to skip)
Wrong guess! Try again.
 1 ?  ?  ?  ?  ?  ?  ?  ?  ?  ? 4 ?  ?  ?  ?  ? 1
This random number has 19 digits.
You have 10 chances left to guess it correctly.
(type 'skip' to skip)
Wow, it's a correct guess!!!
 1 ?  ?  ? 3 ?  ?  ?  ?  ?  ? 4 ?  ?  ?  ?  ? 1
This random number has 19 digits.
You have 10 chances left to guess it correctly.
(type 'skip' to skip)
Wow, it's a correct guess!!!
 1 ?  ?  ? 3 ? 7 ?  ? 7 ?  ? 4 ? 7 ?  ?  ? 1
This random number has 19 digits.
You have 10 chances left to guess it correctly.
(type 'skip' to skip)
Sorry to see you go, The random number was 1999397897894979861.
```

Now, we will check whether our Combined Linear Congruential Generator is really random or not.

We will implement The Kolmogorov-Smirnov test for Normality.

In [5]:
```
import random
from math import sqrt
D_plus =[]; D_minus =[]; random_value =[]  #setting up blank list for D+, D- and values.

for i in range(0, len(rval)):       #Ranking the N random numbers.
    random_value.append(random.random())
    random_value.sort()

for i in range(1, len(rval) + 1):       #Calculating the max(i/N - R_i).
    x = i / len(rval) - random_value[i-1]
    D_plus.append(x)

for i in range(1, len(rval) + 1):       #Calculating the max(R_i-(i-1)/N).
    y = (i-1)/len(rval)
    y = random_value[i-1]-y
    D_minus.append(y)

ans = max(sqrt(len(rval))*D_plus[i-1], sqrt(len(rval))*D_minus[i-1])  #Calculating the max(D+, D-)
D_alpha = 1.36/sqrt(len(rval))          #from reference materials.
print('The value of D is :', ans)
print('The value of D_alpha is :', D_alpha)
if ans > D_alpha:
    print('So, we find that the results reject Uniformity.')
else:
    print('It fails to reject the Null Hypothesis.')
```

```
The value of D is : 0.11046467308898456
The value of D_alpha is : 0.024830089273567533
So, we find that the results reject Uniformity.
```

Exporting our random numbers to a .csv file for brevity.

In [6]:
```
textfileclcg = open("random_values_clcg.csv", "w") #for the actual random numbers.
name_clg = [str(i) for i in yval]
for element in name_clg:
    textfileclcg.write(element + "\n")
textfileclcg.close()
```

In [7]:
```
textfileclcg2 = open("random_0_to_1_clcg.csv", "w") #for the random numbers generated between 0 and 1.
name_clg2 = [str(i) for i in rval]
for element in name_clg2:
    textfileclcg2.write(element + "\n")
textfileclcg2.close()
```