Simulating a doctor’s waiting room

**Goal:** Simulate the queuing behavior at a doctor’s office.

**Assumptions:**

1. Patients arrive on the minutes between 9:00 am and 11:59 am.
2. At most one patient arrives during any minute.
3. The probability that a patient arrives in any one minute is 0.075.
4. Each patient needs to meet with the doctor for 15 minutes.

**Expectations:**

1. How many patients does the doctor expect to see in the day?
2. How much time does the doctor expect to spend with patients?

Simulating this situation: For [
Dealing with the waiting

Integrate the *waiting* aspect of a ‘waiting room’ into the simulation:

An arriving patient will wait when ____________________________.

**Define:**

\[
\begin{align*}
\text{nwait} & = \# \text{ patients waiting} \\
\text{endTime} & = \text{end of patient} \\
\text{busy} & = \begin{cases} 
1 & \text{if doctor busy} \\
0 & \text{if doctor free}
\end{cases}
\end{align*}
\]

Pseudocode:

- Zero out the counters.
- For \( i \) from 0 up to 180,
  - If the doctor is finishing with a patient at time \( i \), then set \text{busy}=0.
  - Determine if a new patient arrives (random, probability 0.075). If so, set \text{newPatient} to 1; otherwise set \text{newPatient} to 0.
  - If \text{newPatient} == 1, add one to the number waiting (\text{nwait}++)
  - If the doctor is not busy AND there is a patient waiting,
    - Subtract one from the number waiting (\text{nwait}--)
    - Set the doctor to be busy (\text{busy} = 1)
    - Set the time when the doctor is not busy to \( i + 15 \).
Dealing with the waiting

```plaintext
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
   If[endTime == i, busy = 0];
   newPatient = If[RandomReal[] <= 0.075, 1, 0];
   If[newPatient == 1, nwait++];
   If[busy == 0 && nwait > 0,
      nwait--; busy = 1; endTime = i + 15];
]

- For i from 0 up to 180,
  - If the doctor is finishing with a patient at time i, then set busy=0.
  - Determine if a new patient arrives (random, probability 0.075).
    If so, set newPatient to 1; otherwise set newPatient to 0.
  - If newPatient == 1, add one to the number waiting (nwait++)
  - If the doctor is not busy AND there is a patient waiting,
    - Subtract one from the number waiting (nwait--)
    - Set the doctor to be busy (busy = 1)
    - Set the time when the doctor is not busy to i + 15.
```
What does the simulation tell us?

We did the simulation, but what was the point?

- How much of the day will the doctor will be busy?
- What is the average number of patients in the waiting room?
- How many people are in the waiting room at noon?
- How late will the doctor stay after noon?

What statistics do we need to keep track of to answer these questions?

This is just one instance; the power of simulation comes from running the model many times and understanding the average behavior.
Gathering data

How many people are in the waiting room at noon?

\[
nwait = 0; \text{busy} = 0; \text{endTime} = 0;
\]

\[
\text{For}[i = 0, i < 180, i++,
\text{If}[\text{endTime} == i, \text{busy} = 0];
\text{newPatient} = \text{If}[\text{RandomReal[]} <= 0.075, 1, 0];
\text{If}[\text{newPatient} == 1, nwait++];
\text{If}[\text{busy} == 0 \&\& nwait > 0,
\text{nwait}--; \text{busy} = 1; \text{endTime} = i + 15];
];
\]

\[
nwait \leftarrow [\text{Outputs the value after the loop ends.}]
\]
Running many trials

How many people are in the waiting room at noon?

Simulate 1000 times using a Table command, generate a histogram.

\[
\text{trials} = \text{Table}[nwait = 0; \text{busy} = 0; \text{endTime} = 0; \text{For}[i = 0, i < 180, i++, \text{If}[\text{endTime} == i, \text{busy} = 0]; \text{newPatient} = \text{If}[\text{RandomReal[]} \leq 0.075, 1, 0]; \text{If}[\text{newPatient} == 1, \text{nwait}++]; \text{If}[\text{busy} == 0 \&\& \text{nwait} > 0, \text{nwait}--; \text{busy} = 1; \text{endTime} = i + 15]; ]; \text{nwait }, \{j,1000\}]
\]

Mean[trials] $\rightarrow [\text{Average: 3.105}]$

Histogram[trials]
Gathering data

How late will the doctor stay after noon?

nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
    If[endTime == i, busy = 0];
    newPatient = If[RandomReal[] <= 0.075, 1, 0];
    If[newPatient == 1, nwait++];
    If[busy == 0 && nwait > 0,
        nwait--; busy = 1; endTime = i + 15];
];

*****

↑ [How to calculate how long the doctor has to stay after noon?]

Mean: 51 minutes (does this make sense?)
Gathering and plotting time-dependent data

How much of the day will the doctor will be busy?
Keep track of if the doctor is busy by using a variable `isBusy`.

```math
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
    If[endTime == i, busy = 0];
    newPatient = If[RandomReal[] <= 0.075, 1, 0];
    If[newPatient == 1, nwait++];
    If[busy == 0 && nwait > 0,
        nwait--; busy = 1; endTime = i + 15];
    isBusy[i] = busy;  \[this copies busy into isBusy[i].\]
];  \[Puts data into a list.\]
busyList = Table[isBusy[i], i, 0, 179]
Total[busyList]  \[Total time busy.\]
ListLinePlot[busyList]
```
Gathering and plotting time-dependent data

- What is the average number of patients in the waiting room?

Keep track of number of waiting patients by using a variable `numWait`.  

```plaintext
nwait = 0; busy = 0; endTime = 0;
For[i = 0, i < 180, i++,
    If[endTime == i, busy = 0];
    newPatient = If[RandomReal[] <= 0.075, 1, 0];
    If[newPatient == 1, nwait++];
    If[busy == 0 && nwait > 0,
        nwait--; busy = 1; endTime = i + 15];
    numWait[i]=nwait;  ←− [this copies nwait into numWait[i].]
];  ↓ [Puts data into a list.]
waitList=Table[numWait[i],i,0,179]
m=Mean[waitList]  ←− [Average patients.]
p1=ListLinePlot[waitList];
p2=Plot[m,x,0,179];
Show[p1,p2]
```