# S7001E — Lab 1 - MATLAB Assignment

- For this lab, you may work in groups of maximum two students. Each group should hand in a concise report documenting and explaining the results for each of the exercises.
- The MATLAB code should consist of a separate script file, named `q1.m` for question one, `q2.m` for question two, etc. These m-files should be included as appendices to the report (and also uploaded separately to Canvas).
- Some helpful MATLAB commands: `help` `rand` `randn` `plot` `hist` `find` `break`

  type `help` *command* within MATLAB to learn more about them.
- **Please find the lab report deadline in Canvas**.

## Fun with a die (simple experiment)

The following MATLAB code, is one way to simulate rolling a fair six-sided die. (There are certainly more efficient ways, and you are encouraged to pursue an efficient, vectorized version!) Nonetheless the version below may be useful here.):

```
p = [1/6 1/6 1/6 1/6 1/6 1/6 ];     % probability of each face
P = [0 cumsum(p)] ;

roll = zeros(N,1);                  % vector to hold results of each roll
                                    % (the memory is "pre-allocated" in this
                                    % way to speed up Matlab processing

for i=1:N,                          % loop over number of rolls
  x=rand(1,1);

  for j=2:length(P),                % determine result of each roll
    if( (P(j-1)<x) & (x<P(j)) )
      roll(i) = j-1;
      break
    end
  end

end
```

An example of running the code, within MATLAB follows:

```
>> N=5;
>> dice
>> roll

roll =
     4
     5
     6
     5
```

1. Verify that the above code is working properly. You might do this by simulating a LARGE number of rolls, and then seeing if the probability of each face is $\frac{1}{6}$. (The `find` command is quite useful here.)

   (a) For $N = 1000$, determine the fraction of occurrences for each face to the number of total rolls. Use this as an estimate of the probability of each face. Comment on your results.

(b) Similarly, use the `hist` command with 6 bins and plot the histogram. In a different figure, show the theoretical probability density function (pdf). What is the relationship between this histogram and the pdf?

(c) Scale the histogram properly, so that it may be considered as an estimate of the pdf.

2. Modify the above to simulate a four sided die, having the face probabilities of $f_1 = 0.1$, $f_2 = 0.2$, $f_3 = 0.4$, $f_4 = 0.3$,

   (a) Repeat 1(a) for this new die.

   (b) Repeat 1(b) for this new die.

   (c) In a new plot, plot the theoretical probability distribution function (PDF). Create an approximation to this theoretical PDF using the `cumsum` command with the `hist` command.

| Fun with two dice (combined experiments) |
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3. Consider the *combined experiment* of rolling both your fair six-sided die (die #1) and your unfair four-sided die (die #2) .

   (a) Determine the theoretical probability of the event of "sum of die #1 and die #2 is an even number".

   (b) Run a large number of combined rolls, and see if your simulation reflects your theoretical answer.

   (c) Determine the theoretical probability of the event of "sum of die #1 and die #2 is an even number given that die #2 is greater than 2".

   (d) Run a large number of combined rolls, and see if your simulation reflects your theoretical answer.

| Binary communication channel |
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4. Construct a simulator of a binary communication channel where the probability of making an error in the transmission of a single binary symbol (a bit) is 0.001. The digits that are sent along the channel should be independent.

   (a) Determine the theoretical probability of 2 or fewer errors in the transmission of 100 bits.

   (b) Simulate transmission of many blocks of 100 bits over the channel. Does the fraction of blocks that contain 2 or fewer errors agree with your theoretical result in (a)?

   (c) Determine the theoretical probability that there were no errors in a block of 100 bits, given that less than 2 errors occurred when transmitting the block.

   (d) Check your result from (c) with a simulation.

| Continuous random variables |
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5. Use the `randn` function in MATLAB to generate a vector $X$ of 100 independent samples from a Gaussian distribution with mean $\mu = 5$ and variance $\sigma^2 = 3$. (Sometimes we write $X \sim \mathcal{N}(5, 3)$.)

   (a) Calculate the mean and variance of your realization of $X$. Do they agree with the theoretical mean and variance?

   (b) Try again with 10,000 points. Comment on your results and explain.

   (c) On the same plot, produce a properly scaled histogram and theoretical pdf curve.

   (d) Using the `find` command, determine what fraction of points fall between 1 and 2 (that is, $\{1 \leq X \leq 2\}$ ).

   What is the theoretical probability that any point of $X$ falls in this range? (Refer to discussion in the Stark & Woods textbook on pages 89-95 [4th ed.], 67-71 [3rd ed.]).