Hand-Made Central Limit Theorem

In [7]:
```
import numpy as np
import matplotlib.pyplot as plt
import scipy.stats as sts
import math
%matplotlib inline
```

Central Limit Theorem says that if we have a distribution $F(X)$ with expected value μ and dispersion σ^2, and we select n i.i.d. random variables $X_1, X_2, \ldots, X_n$, then their mean $\bar{X}$ is distributied normally with dispersion σ^2/n and mean μ:

$$\bar{X}_n \approx N(\mathbb{E}\mu, \sigma^2/n)$$

Let us check if it really so for the case when $F(X)$ is a uniform distribution:

Define uniform distribution from a to b:

In [8]:
```
a = 1
b = 5

uniform_rv = sts.uniform(a, b-a)

uniform_rv.rvs(10)
```

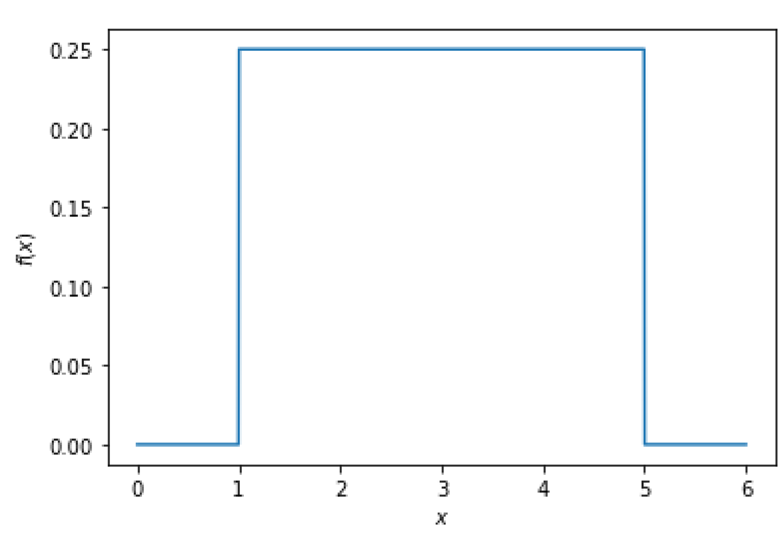
Out[8]:
```
array([2.52015047, 4.91672774, 3.6325683 , 1.59803618, 2.10042416,
       2.41479864, 4.92748426, 3.30183406, 3.0959588 , 4.31850694])
```

Task 1. Plot the probability density function of the uniform distribution:

In [112…
```
x = np.linspace(0,6,1000)
pdf = uniform_rv.pdf(x)
plt.plot(x, pdf)

plt.ylabel('$f(x)$')
plt.xlabel('$x$')
```

Out[112…
```
Text(0.5, 0, '$x$')
```



We are going to create *samples_no = 1000* sets of the size *n = 50* and calculate mean $\bar{X}$ of each sample and store the results in the vector *sample_means*:

In [113…
```
samples_no = 1000
```

In [114…
```
n = 50
sample_means = np.empty(samples_no)
```

Task 2: Create a cycle for *i* from 0 to *samples_no*, in which you create a sample of the size *n*, calculate the mean of the sample and store its value in the vector *sample_means*

In [123…
```
i = 0
while i <= samples_no:
    sample = np.random.choice([3,4,5,6,7,8], size = n)
    np.append(sample_means, np.mean(sample))
    i=i+1

print(sample_means)
```

```
[ 0.00000000e+000  6.93088031e-310  0.00000000e+000  6.93088031e-310
  6.93088031e-310  5.43472210e-323  0.00000000e+000  3.95252517e-323
  0.00000000e+000  0.00000000e+000  5.14532891e+216  0.00000000e+000
  0.00000000e+000 -5.21081117e+031  0.00000000e+000  0.00000000e+000
  1.18729270e+068  0.00000000e+000  0.00000000e+000  2.36323529e-026
  0.00000000e+000  0.00000000e+000 -4.24116690e+015  0.00000000e+000
  0.00000000e+000 -2.17660496e-194  0.00000000e+000  0.00000000e+000
 -1.42523871e+128  0.00000000e+000  0.00000000e+000 -9.34689216e-043
  0.00000000e+000  0.00000000e+000 -5.18805516e-307  0.00000000e+000
  0.00000000e+000  9.05664082e-006  0.00000000e+000  0.00000000e+000
 -1.05901774e+080  0.00000000e+000  0.00000000e+000 -1.06812671e-156
  0.00000000e+000  0.00000000e+000 -2.15091052e+022  0.00000000e+000
  0.00000000e+000  1.44494218e+001  0.00000000e+000  0.00000000e+000
  9.23277931e-179  0.00000000e+000  0.00000000e+000  3.29354848e-093
  0.00000000e+000  0.00000000e+000  0.00000000e+000  0.00000000e+000
  0.00000000e+000 -4.79160831e+058  8.48798316e-313  0.00000000e+000
 -5.58796348e-075  0.00000000e+000  0.00000000e+000  8.32206859e-190
  6.93088000e-310  6.93088017e-310 -3.05111241e+062  6.93088031e-310
  6.93088017e-310  4.60347913e-252  6.93088022e-310  6.93088017e-310
 -4.27225907e-277  6.93088022e-310  6.93088017e-310  1.13123094e+192
  6.93088032e-310  6.93088017e-310 -3.69996998e-139  6.93088032e-310
  6.93088017e-310  1.59639856e+033  6.93088027e-310  4.41915047e-314
 -1.01813793e+154  6.93088031e-310  6.93088017e-310 -3.97218764e+092
  6.93088031e-310  6.93088017e-310 -7.15946385e+126  6.93088022e-310
  6.93088017e-310  1.35996116e+069  6.93088012e-310  6.93088017e-310
  6.61396197e-031  6.93088007e-310  6.93088017e-310  9.90506552e+111
  6.93087985e-310  6.93088017e-310  2.57949713e+254  6.93088027e-310
  6.93088017e-310  5.85416743e-245  6.93088027e-310  6.93088017e-310
  7.20757425e+205  6.93088027e-310  6.93088017e-310 -7.56349865e+207
  6.93088008e-310  6.93088017e-310 -7.31729360e-005  6.93088008e-310
  6.93088032e-310  1.17006500e-160  6.93088012e-310  6.93088032e-310
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  6.93088032e-310 -1.84834305e-193  6.93087993e-310  6.93088032e-310
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  7.29288888e+114  6.93088017e-310  6.93088027e-310  1.09847235e+215
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 -5.54148813e+017  6.93088027e-310  6.93088032e-310  7.29374180e+030
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  8.07955774e+001  4.58836364e+001  8.11002457e+001  4.58836364e+001
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  8.81076167e+001  4.58836364e+001  8.84122850e+001  4.58836364e+001
  8.87169533e+001  4.58836364e+001  8.90216216e+001  4.58836364e+001
  8.93262899e+001  4.58836364e+001  8.96309582e+001  4.58836364e+001
  8.99356265e+001  4.58836364e+001  9.02402948e+001  4.58836364e+001
  9.05449631e+001  4.58836364e+001  9.08496314e+001  4.58836364e+001
  9.11542998e+001  4.58836364e+001  9.14589681e+001  4.58836364e+001
  9.17636364e+001  4.58836364e+001  9.20683047e+001  4.58836364e+001
  9.23729730e+001  4.58836364e+001  9.26776413e+001  4.58836364e+001
  9.29823096e+001  4.58836364e+001  9.32869779e+001  4.58836364e+001
  9.35916462e+001  4.58836364e+001  9.38963145e+001  4.58836364e+001
  9.42009828e+001  4.58836364e+001  9.45056511e+001  4.58836364e+001
  9.48103194e+001  4.58836364e+001  9.51149877e+001  4.58836364e+001
  9.54196560e+001  4.58836364e+001  9.57243243e+001  4.58836364e+001
  9.60289926e+001  4.58836364e+001  9.63336609e+001  4.58836364e+001
  9.66383292e+001  4.58836364e+001  9.69429975e+001  4.58836364e+001
  9.72476658e+001  4.58836364e+001  9.75523342e+001  4.58836364e+001
  9.78570025e+001  4.58836364e+001  9.81616708e+001  4.58836364e+001
  9.84663391e+001  4.58836364e+001  9.87710074e+001  4.58836364e+001
  9.90756757e+001  4.58836364e+001  9.93803440e+001  4.58836364e+001
  9.96850123e+001  4.58836364e+001  9.99896806e+001  4.58836364e+001
  1.00294349e+002  4.58836364e+001  1.00599017e+002  4.58836364e+001
  1.00903686e+002  4.58836364e+001  1.01208354e+002  4.58836364e+001
  1.01513022e+002  4.58836364e+001  1.01817690e+002  4.58836364e+001
  1.02122359e+002  4.58836364e+001  1.02427027e+002  4.58836364e+001
  1.02731695e+002  4.58836364e+001  1.03036364e+002  4.58836364e+001
  1.03341032e+002  4.58836364e+001  1.03645700e+002  4.58836364e+001
  1.03950369e+002  4.58836364e+001  1.04255037e+002  4.58836364e+001
  1.04559705e+002  4.58836364e+001  1.04864373e+002  4.58836364e+001
  1.05169042e+002  4.58836364e+001  1.05473710e+002  4.58836364e+001
  1.05778378e+002  4.58836364e+001  1.06083047e+002  4.58836364e+001
  1.06387715e+002  4.58836364e+001  1.06692383e+002  4.58836364e+001
  1.06997052e+002  4.58836364e+001  1.07301720e+002  4.58836364e+001
  1.07606388e+002  4.58836364e+001  1.07911057e+002  4.58836364e+001
  1.08215725e+002  4.58836364e+001  1.08520393e+002  4.58836364e+001
  1.08825061e+002  4.58836364e+001  1.09129730e+002  4.58836364e+001
  1.09434398e+002  4.58836364e+001  1.09739066e+002  4.58836364e+001
  1.10043735e+002  4.58836364e+001  1.10348403e+002  4.58836364e+001
  1.10653071e+002  4.58836364e+001  1.10957740e+002  4.58836364e+001
  1.11262408e+002  4.58836364e+001  1.11567076e+002  4.58836364e+001
  1.11871744e+002  4.58836364e+001  1.12176413e+002  4.58836364e+001
  1.12481081e+002  4.58836364e+001  1.12785749e+002  4.58836364e+001
  1.13090418e+002  4.58836364e+001  1.13395086e+002  4.58836364e+001
  1.13699754e+002  4.58836364e+001  1.14004423e+002  4.58836364e+001
  1.14309091e+002  4.58836364e+001  1.14613759e+002  4.58836364e+001
  1.14918428e+002  4.58836364e+001  1.15223096e+002  4.58836364e+001
  1.15527764e+002  4.58836364e+001  1.15832432e+002  4.58836364e+001
  1.16137101e+002  4.58836364e+001  1.16441769e+002  4.58836364e+001
  1.16746437e+002  4.58836364e+001  1.17051106e+002  4.58836364e+001
  1.17355774e+002  4.58836364e+001  1.17660442e+002  4.58836364e+001
  1.17965111e+002  4.58836364e+001  1.18269779e+002  4.58836364e+001
  1.18574447e+002  4.58836364e+001  1.18879115e+002  4.58836364e+001
  1.19183784e+002  4.58836364e+001  1.19488452e+002  4.58836364e+001
  1.19793120e+002  4.58836364e+001  1.20097789e+002  2.43556364e+002
  1.20402457e+002  2.43556364e+002  1.20707125e+002  2.43556364e+002
  1.21011794e+002  2.43556364e+002  1.21316462e+002  2.43556364e+002
  1.21621130e+002  2.43556364e+002  1.21925799e+002  2.43556364e+002
  1.22230467e+002  2.43556364e+002  1.22535135e+002  2.43556364e+002
  1.22839803e+002  2.43556364e+002  1.23144472e+002  2.43556364e+002
  1.23449140e+002  2.43556364e+002  1.23753808e+002  2.43556364e+002]
```
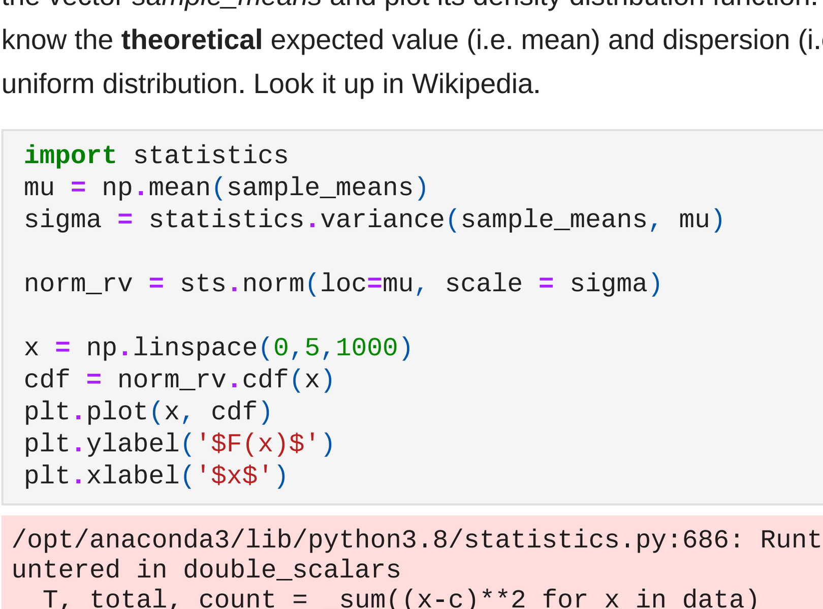

Task 3: plot histogram of the vector sample_means. It should have a bell-like shape:

In [133…
```
plt.hist(sample_means, density = True)
plt.ylabel('Fraction of Samples')
plt.xlabel('$x$')
#You should get something like this:
```

Out[133…
```
Text(0.5, 0, '$x$')
```



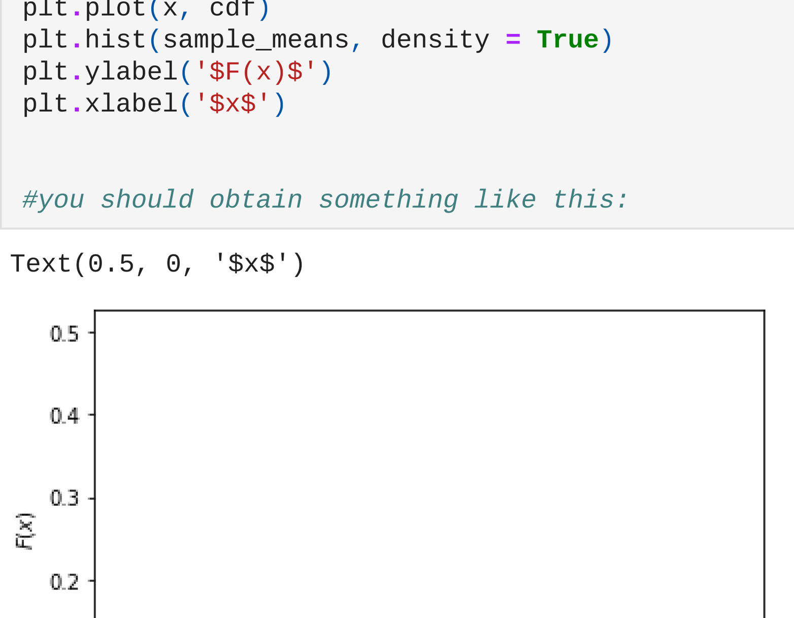
You are going to compare the obtained histogram from Task 3 with the normal distribution

Task 4: Create a normal distribution such, that it will be a distribution of the data you store in the vector *sample_means* and plot its density distribution function. Hint: to do that, you should know the **theoretical** expected value (i.e. mean) and dispersion (i.e. variance) of your initial uniform distribution. Look it up in Wikipedia.

In [135…
```
import statistics
mu = np.mean(sample_means)
sigma = statistics.variance(sample_means, mu)

norm_rv = sts.norm(loc=mu, scale = sigma)

x = np.linspace(0,5,1000)
cdf = norm_rv.cdf(x)
plt.plot(x, cdf)
plt.ylabel('$F(x)$')
plt.xlabel('$x$')
```

```
/opt/anaconda3/lib/python3.8/statistics.py:686: RuntimeWarning: overflow enco
untered in double_scalars
  T, total, count = _sum((x-c)**2 for x in data)
```

Out[135…
```
Text(0.5, 0, '$x$')
```



Task 5 Plot the histogram from Task 3 and the distribution density function from Task 4 *in the same Graph*. Do they look similar?

In [136…
```
plt.plot(x, cdf)
plt.hist(sample_means, density = True)
plt.ylabel('$F(x)$')
plt.xlabel('$x$')


#you should obtain something like this:
```

Out[136…
```
Text(0.5, 0, '$x$')
```