**Numerical Integration : scipy.integrate**

When integrating a function analytically is not possible or is extremely difficult to integrate , numerical integration methods can be used.

SciPy provides functions to perform integrations from ordinary differential equations to trapezoidal rules.

Numerical Integration is also sometimes called Quadrature. It performs single integration of a function f(x) in the range which is fixed from a to b. In scipy it is the quad function. If the integration is double , triple or more , the functions used are dblquad, tplquad and nquad respectively.

Ordinary Differential equations can also be integrated using scipy.integrate.odeint.

**Example 1: Single Integration**

*import scipy.integrate*

*from numpy import exp*

*f= lambda x:exp(-x\*\*3)*

*#f is the function to be integrated, 0 is the lower limit and 1 is the upper limit*

*print(scipy.integrate.quad(f, 0, 1))*

*Output: (0.8075111821396714, 8.965175070537417e-15)*

**Example 2: Double Integration**

*import scipy.integrate*

*from numpy import exp*

*from math import sqrt*

*f = lambda x, y : 16\*x\*y*

*g = lambda x : 0*

*h = lambda y : sqrt(1-4\*y\*\*2)*

*print(scipy.integrate.dblquad(f, 0, 0.5, g, h))*

*Output : (0.5, 1.7092350012594845e-14)*

**Example 3: Integrating a Bessel Function**

*import scipy.integrate as integrate*

*import scipy.special as special*

*result = integrate.quad(lambda x: special.jv(3.5,x), 0, 5.5)*

*result*

**Example 4: Integrating a Ordinary Differential Equation**

Solving the ODE : dy/dt = -2 y between t = 0...4, with the initial condition y(t=0) = 1

*def calc\_derivative(ypos, time):*

*return -2 \* ypos*

*from scipy.integrate import odeint*

*import numpy as np*

*time\_vec = np.linspace(0, 4, 10)*

*y = odeint(calc\_derivative, y0=1, t=time\_vec)*

*print(y)*

*Output:*

*[[1.00000000e+00]*

*[4.11112313e-01]*

*[1.69013313e-01]*

*[6.94834400e-02]*

*[2.85654998e-02]*

*[1.17436289e-02]*

*[4.82795070e-03]*

*[1.98483034e-03]*

*[8.15986861e-04]*

*[3.35461690e-04]]*