UNIT 6 Euler’s Method to Solve Ordinary Differential Equations

1. **To Solve First Order Differential Equation by Euler Method and compare it with Exact Solution and Inbuilt Function.**

**# import libraries**

import numpy as np

import matplotlib.pyplot as plt

from scipy.integrate import odeint

def f(y,x): **#Differential Equation to solve**

return np.exp(x)

def f\_exact(y,x): **#Exact Equation**

return np.exp(x)

print("\n\n\tMehendi Hasan\n\n\t2230248\n\n")

**#User Inputs**

x0=float(input("Enter Initial value of X: "))

y0=float(input("Enter Value of Y at Initial value of X: "))

h=float(input("Enter Step Size: "))

b=float(input("Enter last value of interval: "))

x\_values=np.arange(0,b+h,h)

y\_values=np.zeros(len(x\_values))

y\_exact=np.zeros(len(x\_values))

y\_odeint=np.zeros(len(x\_values))

x\_values[0]=x0

y\_values[0]=y0

for i in range(len(y\_values)-1):

y\_values[i+1]=y\_values[i] + h\*f(y\_values[i],x\_values[i])

y\_exact=np.array(f\_exact(y\_values,x\_values))

y\_odeint=odeint(f,y0,x\_values)

**#plot**

plt.subplot(3,1,1)

plt.plot(x\_values,y\_values,label="F(x) Eulers",color="red")

plt.xlabel("X Points")

plt.ylabel("Y Points")

plt.grid()

plt.legend()

plt.subplot(3,1,2)

plt.plot(x\_values,y\_exact,label="F(x) Exact",color="blue")

plt.xlabel("X Points")

plt.ylabel("Y Points")

plt.grid()

plt.legend()

plt.subplot(3,1,3)

plt.plot(x\_values,y\_odeint,label="F(x) Odeint",color="green")

plt.xlabel("X Points")

plt.ylabel("Y Points")

plt.grid()

plt.legend()

plt.suptitle("Mehendi Hasan B.SC.(H) Physics 2230248\nTo Solve First Order Differential Equation by Euler Method and compare it with Exact Solution and Inbuilt Function.")

plt.show()

1. **To Plot Newton's cooling law ODE by Euler method, Exact solution & Inbuilt solver.**

**#libraries**

**import matplotlib.pyplot as plt**

**import numpy as np**

**import scipy.integrate as it**

**def f(T,t): # Differential Equation of cooling**

**return (-K)\*(T-Ts)**

**print("\n\n\tMehendi Hasan\n\n\t2230248\n\n")**

**print("Newton's Law of Cooling\n\nTemperature is in Degree Celsius and time is in secons\n\n")**

**T0=int(input("Enter initial Temperature of Object: "))**

**Ts=int(input("Enter Surrounding temperature: "))**

**t=int(input("Enter time from t=0, at which temperature of Object to be calculated: "))**

**h=0.001 #step size**

**K=0.1 #cooling constant**

**x\_points=np.arange(0,t+h,h)**

**T=np.zeros(len(x\_points))**

**TExact=np.zeros(len(x\_points))**

**T[0]=T0**

**TExact[0]=T0**

**for i in range(len(x\_points)-1):**

**T[i+1]= (T[i] + (h\*(f(T[i],x\_points))))**

**TExact = Ts + ((T0-Ts)\*np.exp((-K)\*(x\_points)))**

**solOdeint=it.odeint(f,T0,x\_points)**

**#ploting**

**plt.subplot(3,1,1)**

**plt.plot(x\_points,T,label="Euler's Solution")**

**plt.grid()**

**plt.title("Euler's Method")**

**plt.xlabel("Time")**

**plt.ylabel("Temperature of Object")**

**plt.legend()**

**plt.subplot(3,1,2)**

**plt.plot(x\_points,TExact,label='Exact Equation Solution')**

**plt.grid()**

**plt.title("Exact Equation")**

**plt.xlabel("Time")**

**plt.ylabel("Temperature of Object")**

**plt.subplot(3,1,3)**

**plt.plot(x\_points,solOdeint,label='Odient Solution')**

**plt.grid()**

**plt.title("Odeient Solution")**

**plt.xlabel("Time")**

**plt.ylabel("Temperature of Object")**

**plt.legend()**

**plt.suptitle("Mehendi Hasan B.SC.(H) Physics 2230248\nTo Plot Newton's cooling law ODE by Euler method, Exact solution & Inbuilt solver")**

**plt.show()**

1. **To Plot Radioactive Decay ODE by Euler method, Exact solution & Inbuilt solver.**

**#importing libraries**

**import matplotlib.pyplot as plt**

**import numpy as np**

**import scipy.integrate as it**

**def diff\_Equ(N,t):**

**return (-1)\*(K)\*(N)**

**def Exact\_Equ(N,t):**

**return N0\*(np.exp((-1)\*(K)\*(t)))**

**print("\n\n\tMehendi Hasan\n\n\t2230248\n\nRadioactive Decay \n\nTime is in Seconds\n")**

**#itaking input from user**

**N0=int(input("Enter Number of Parent Atoms at t=0: "))**

**t=int(input("Enter time instant at which Remaining of Parent Atoms to be calculated: "))**

**K=float(input("Enter Radioactive Decay constant value: ")) # Radioactive Decay Constant**

**h=0.001 # Step size for Euler method**

**t\_array=np.arange(0,t+h,h) #initializing time array(independent Variable)**

**Y\_differential=np.zeros(len(t\_array)) #Initializing array for values of dependent variable(Euler's metod)**

**Y\_Exact=np.zeros(len(t\_array)) # #Initializing array for values of dependent variable(Solution equation)**

**Y\_differential[0] = Y\_Exact[0] = N0 #Initial values of dependent variable Y at independent variable t=0**

**for i in range(len(t\_array)-1):**

**Y\_differential[i+1]=Y\_differential[i] + h\*(diff\_Equ(Y\_differential[i],t\_array[i]))**

**Y\_Exact=Exact\_Equ(Y\_Exact,t\_array) # solution equation**

**solOdeint=it.odeint(diff\_Equ,N0,t\_array) # odeint solution**

**#ploting all the values of dependent variable with respect to independent variable**

**plt.subplot(3,1,1)**

**plt.plot(t\_array,Y\_differential,color="green",label="Euler's Solution")**

**plt.grid()**

**plt.xlabel("Time (Second)")**

**plt.ylabel("No. of parent Atoms")**

**plt.legend()**

**plt.subplot(3,1,2)**

**plt.plot(t\_array,Y\_Exact,color="red",label='Exact Equation Solution')**

**plt.grid()**

**plt.xlabel("Time (Second)")**

**plt.ylabel("No. of parent Atoms")**

**plt.legend()**

**plt.subplot(3,1,3)**

**plt.plot(t\_array,solOdeint,color="blue",label='Odeint Solution')**

**plt.grid()**

**plt.xlabel("Time (Second)")**

**plt.ylabel("No. of parent Atoms")**

**plt.legend()**

**plt.suptitle("Mehendi Hasan B.SC.(H) Physics 2230248\nTo Plot Radioactive Decay ODE by Euler method, Exact solution & Inbuilt solver.")**

**plt.show()**

1. **To Plot Charging and Discharging of a capacitor in RC circuit ODE with DC source by Euler Method, Exact solution, Inbuilt solver.**

**#importing libraries**

import matplotlib.pyplot as plt

import numpy as np

import scipy.integrate as it

def diff\_equ\_charging(q,t): **# Differential Equation of Charging**

return ((C\*E - q)/(R\*C))

def Exact\_equ\_charging(t): **#Solution equation of Differential Equation of Charging**

return (C\*E)\*(1-(np.exp(((-1)\*t)/(R\*C))))

def diff\_equ\_discharging(q,t): **# Differential Equation of Discharging**

return ((-1)\*q)/(R\*C)

def Exact\_equ\_discharging(t): **#Solution equation of Differential Equation of Discharging**

return ((C\*E)\*(np.exp(((-1)\*t)/(R\*C))))

print("\n\n\tMehendi Hasan\n\n\t2230248\n\nRC Circuit Charging and Discharging of Capacitor\n\n")

print("Capacitance is in Farad, resistance is in ohm,time is in second,charge in coulomb,voltage in volts.\n\n")

**#taking inputs from user for the terms envoled in equations**

C=float(input("Enter Capacitance of Capacitor: "))

E=float(input("Enter EMF of Battery: "))

R=float(input("Enter Resistance of Resistor: "))

t=float(input("Enter time instant at which charge on capacitor to be calculated: "))

h=0.1 #Step size

Qmax=C\*E **#max value of charge on capacitor**

t\_array=np.arange(0,t+h,h) **#initializing time array(independent Variable)**

#Charging of Capacitor

Y\_diff\_charging=np.zeros(len(t\_array)) **#Initializing array for values of dependent variable(Euler's method)**

Y\_Exact\_charging=np.zeros(len(t\_array)) **#Initializing array for values of dependent variable(Solution equation)**

Y\_Exact\_charging[0] = Y\_diff\_charging[0] = 0 **#Initial values of dependent variable Y at dependent variable t=0**

for i in range(len(t\_array)-1**): #updating values of dependent variable**

Y\_diff\_charging[i+1]=Y\_diff\_charging[i] + h\*(diff\_equ\_charging(Y\_diff\_charging[i],t\_array[i])) **#Euler's Method**

Y\_Exact\_charging=Exact\_equ\_charging(t\_array) **#Solution Equation**

solOdeintCharging=it.odeint(diff\_equ\_charging,Y\_diff\_charging[0],t\_array) **#Odeint solution**

**#Discharging of Capacitor**

Y\_diff\_discharging=np.zeros(len(t\_array)) **#Initializing array for values of dependent variable(Euler's method)**

Y\_Exact\_discharging=np.zeros(len(t\_array)) **#Initializing array for values of dependent variable(Solution equation)**

Y\_Exact\_discharging[0] = Y\_diff\_discharging[0] = Qmax **#Initial values of dependent variable Y at independent** variable t=0

for i in range(len(t\_array)-1): **#updating values of dependent variable**

Y\_diff\_discharging[i+1]=Y\_diff\_discharging[i] + h\*(diff\_equ\_discharging(Y\_diff\_discharging[i],t\_array[i])) **#Euler's Method**

Y\_Exact\_discharging=Exact\_equ\_discharging(t\_array) **#Solution Equation**

solOdeintDischarging=it.odeint(diff\_equ\_discharging,Y\_diff\_discharging[0],t\_array) **#Odeint solution**

**#ploting all the values of dependent variable with respect to independent variable**

plt.subplot(3,2,2)

plt.plot(t\_array,Y\_diff\_charging,color='blue',label="Charge")

plt.xlabel("Time")

plt.ylabel("Charge at Capacitor")

plt.title("Euler's Solution of Charging")

plt.legend()

plt.subplot(3,2,4)

plt.plot(t\_array,Y\_Exact\_charging,color='red',label="Charge")

plt.xlabel("Time")

plt.ylabel("Charge at Capacitor")

plt.title("Exact Equation of Charging")

plt.legend()

plt.subplot(3,2,1)

plt.plot(t\_array,Y\_diff\_discharging,color='orange',label="Charge")

plt.xlabel("Time")

plt.ylabel("Charge at Capacitor")

plt.title("Euler's Solution of Discharging")

plt.legend()

plt.subplot(3,2,3)

plt.plot(t\_array,Y\_Exact\_discharging,color='green',label="Charge")

plt.xlabel("Time")

plt.ylabel("Charge at Capacitor")

plt.title("Exact Equation of Discharging")

plt.legend()

plt.subplot(3,2,6)

plt.plot(t\_array,solOdeintCharging,color='orange',label="Charge")

plt.xlabel("Time")

plt.ylabel("Charge at Capacitor")

plt.title("Odeint Solution of Charging")

plt.legend()

plt.subplot(3,2,5)

plt.plot(t\_array,solOdeintDischarging,color='red',label="Charge")

plt.xlabel("Time")

plt.ylabel("Charge at Capacitor")

plt.title("Odeint Solution of Discharging")

plt.legend()

plt.suptitle("Mehendi Hasan B.SC.(H) Physics 2230248\nTo Plot Charging and Discharging of a capacitor in RC circuit ODE with DC source by Euler Method, Exact solution, Inbuilt solver")

plt.show()

1. **To Plot Current in RC circuit and potential ODE with DC source by Euler Method, Exact solution, Inbuilt solver.**

**#importing libraries to be used**

import matplotlib.pyplot as plt

import numpy as np

import scipy.integrate as it

class RC: **# Created a class of RC Circuit which have multiple Functions**

def current(I,t): **# Current v/s time graph using** Euler's Method

return ((-1)\*(I))/(R\*C)

def current\_exact(t): **# Current v/s time graph by ploting the solution equation of ODE**

return I0\*(np.exp((-1)\*t/(R\*C)))

def Vr(Vr,t): **# Voltage across resistor v/s time graph using Euler's Method**

return -Vr/(R\*C)

def VrExact(t**): # Voltage across resistor v/s time graph by ploting the solution equation of ODE**

return V\*(np.exp((-t)/(R\*C)))

def Vc(Vc,t): **# Voltage across capacitor v/s time graph using Euler's Method**

return (1/(R\*C))\*(V-Vc)

def VcExact(t): **# Voltage across capacitor v/s time graph by ploting the solution equation of ODE**

return V\*(1-(np.exp((-t)/(R\*C))))

print("\n\n\tMehendi Hasan\n\n\t2230248\n\nRC Circuit\n\n")

print("Capacitance is in Farad, resistance is in ohm,time is in second,charge in coulomb,voltage in volts.\n\n")

**# input constant values**

R=float(input('Enter the value of resistance in ohms:')) **#resistance**

C=float(input('Enter the value of capacitance in farads:')) **# capacitance**

V=float(input('Enter the value of EMF in volts:')) **# EMF**

T\_fin=float(input('Enter time instant at which current to be measured:')) **# time instant**

h=0.001 **#step size**

time\_array=np.arange(0,T\_fin+h,h)**# X-coordinate (time)**

# Current v/s time

I0=V/R **#current in circuit at t=0**

yPointsCurrent=np.zeros(len(time\_array)) **#initializing Y-coordinates as array of zeros of lenght time array(Euler method )**

yPointsCurrentExact=np.zeros(len(time\_array)) **#initializing Y-coordinates as array of zeros of lenght time array(solution Equation)**

yPointsCurrent[0]=I0 **# initializing Initial value for euler's method**

for i in range(len(time\_array)-1**): # updating the array of zeros with help of euler's method and solution equation**  
 yPointsCurrent[i+1]=yPointsCurrent[i]+h\*RC.current(yPointsCurrent[i],time\_array[i]) **#Euler's Method**

yPointsCurrentExact=RC.current\_exact(time\_array) **# Solution Equation**

solOdeintYPointsCurrent=it.odeint(RC.current,I0,time\_array) **#odeint solution**

**# Voltage across resistor v/s time**

Vr0=V

yPointsVr=np.zeros(len(time\_array)) **#initializing Y-coordinates as array of zeros of lenght time array(Euler method )**

yPointsVrExact=np.zeros(len(time\_array)) **#initializing Y-coordinates as array of zeros of lenght time array(solution Equation)**

yPointsVr[0]=Vr0 **# initializing Initial value for euler's method**

for i in range(len(time\_array)-1): **# updating the array of zeros with help of euler's method and solution equation**

yPointsVr[i+1]=yPointsVr[i]+h\*RC.Vr(yPointsVr[i],time\_array[i]) **#Euler's Method**

yPointsVrExact=RC.VrExact(time\_array) # **Solution Equation**

solOdeintYPointsVr=it.odeint(RC.Vr,Vr0,time\_array) **#odeint solution**

**# Voltage across capacitor v/s time**

Vc0=0

yPointsVc=np.zeros(len(time\_array)) **#initializing Y-coordinates as array of zeros of lenght time array(Euler method )**

yPointsVcExact=np.zeros(len(time\_array)) **#initializing Y-coordinates as array of zeros of lenght time array(solution Equation)**

yPointsVc[0]=Vc0 **# initializing Initial value for euler's method**

for i in range(len(time\_array)-1): **# updating the array of zeros with help of euler's method and solution equation**

yPointsVc[i+1]=yPointsVc[i]+h\*RC.Vc(yPointsVc[i],time\_array[i]) **#Euler's Method**

yPointsVcExact=RC.VcExact(time\_array) # **Solution Equation**

solOdeintYPointsVc=it.odeint(RC.Vc,Vc0,time\_array) **#odeint solution**

**# plot of I v/s t**

plt.subplot(3,2,1)

plt.plot(time\_array,yPointsCurrent,color='red',label="I")

plt.xlabel('Time(s)')

plt.ylabel('Current(amps)')

plt.title("Current v/s time Euler's")

plt.grid('true')

plt.legend()

plt.subplot(3,2,2)

plt.plot(time\_array,yPointsCurrentExact, color='blue',label="I")

plt.xlabel('Time(s)')

plt.ylabel('Current(amps)')

plt.title("Current v/s time Solution Equation")

plt.grid('true')

plt.legend()

**# plot of Vr v/s t**

plt.subplot(3,2,3)

plt.plot(time\_array,yPointsVr,color='red',label="Vr")

plt.plot(time\_array,yPointsVc,color='blue',label="Vc")

plt.xlabel('Time(s)')

plt.ylabel('(volts)')

plt.title("Vr and Vc v/s time Eulers ")

plt.grid('true')

plt.legend()

plt.subplot(3,2,4)

plt.plot(time\_array,yPointsVrExact, color='blue',label="Vr")

plt.plot(time\_array,yPointsVcExact, color='red',label="Vc")

plt.xlabel('Time(s)')

plt.ylabel("(volts)")

plt.title("Vr and Vc v/s time Solution equation")

plt.grid('true')

plt.legend()

plt.subplot(3,2,5)

plt.plot(time\_array,solOdeintYPointsVr, color='blue',label="Vr")

plt.plot(time\_array,solOdeintYPointsVc, color='red',label="Vc")

plt.xlabel('Time(s)')

plt.ylabel("(volts)")

plt.title("Vr and Vc v/s time Odeint Solution")

plt.grid('true')

plt.legend()

plt.subplot(3,2,6)

plt.plot(time\_array,solOdeintYPointsCurrent, color='blue',label="Current")

plt.xlabel('Time(s)')

plt.ylabel("(volts)")

plt.title("Current v/s time Odeint Solution equation")

plt.grid('true')

plt.legend()

plt.suptitle("Mehendi Hasan B.SC.(H) Physics 2230248\nTo Plot Current in RC circuit and potential ODE with DC source by Euler Method, Exact solution, Inbuilt solver.")

plt.show()

1. **To Plot Current in RL circuit ODE with DC source by Euler Method, Exact solution, Inbuilt solver.**

**#importing libraries to be used**

import matplotlib.pyplot as plt

import numpy as np

import scipy.integrate as it

def diffEquation(i,t):

return (V/L)-((R\*i)/L)

def solEquation(i,t):

return (V/R)\*(1-(np.exp((((-1)\*R)\*t)/L)))

print("\n\n\tMehendi Hasan\n\n\t2230248\n\nVariation of curent with time in RL Circuit \n\n")

print("Resistance is in ohm,time is in second,Inductance in henry,voltage in volts.\n\n")

L=float(input("Enter Inductance of Inductor: "))

V=float(input("Enter EMF of Battery: "))

R=float(input("Enter Resistance of Resistor: "))

t=float(input("Enter time instant at which Current through inductor to be calculated: "))

h=0.001  **#step size**

time\_array=np.arange(0,t+h,h)

I0=0 **#current in circuit at t=0**

yPointsCurrent=np.zeros(len(time\_array))

yPointsCurrentExact=np.zeros(len(time\_array))

yPointsCurrent[0]=I0

yPointsCurrentExact[0]=I0

for i in range(len(time\_array)-1):  
yPointsCurrent[i+1]=yPointsCurrent[i]+h\*diffEquation(yPointsCurrent[i],time\_array[i]) **#Euler's Method**

yPointsCurrentExact=solEquation(yPointsCurrentExact,time\_array) **# Solution Equation**

solOdeintYPointsCurrent=it.odeint(diffEquation,I0,time\_array) **#odeint solution**

**# plot of I v/s t**

plt.subplot(1,3,1)

plt.plot(time\_array,yPointsCurrent,color='red',label="I Euler")

plt.xlabel('Time(s)')

plt.ylabel('Current(amps)')

plt.title("Current v/s time Euler's")

plt.grid('true')

plt.legend()

plt.subplot(1,3,2)

plt.plot(time\_array,yPointsCurrentExact, color='blue',label="I")

plt.xlabel('Time(s)')

plt.ylabel('Current(amps)')

plt.title("Current v/s time Solution Equation")

plt.grid('true')

plt.legend()

plt.subplot(1,3,3)

plt.plot(time\_array,solOdeintYPointsCurrent, color='green',label="Current")

plt.xlabel('Time(s)')

plt.ylabel("(volts)")

plt.title("Current v/s time Odeint Solution equation")

plt.grid('true')

plt.suptitle("Mehendi Hasan B.SC.(H) Physics 2230248\nTo Plot Current in RL circuit ODE with DC source by Euler Method, Exact solution, Inbuilt solver.")

plt.legend()

plt.show()