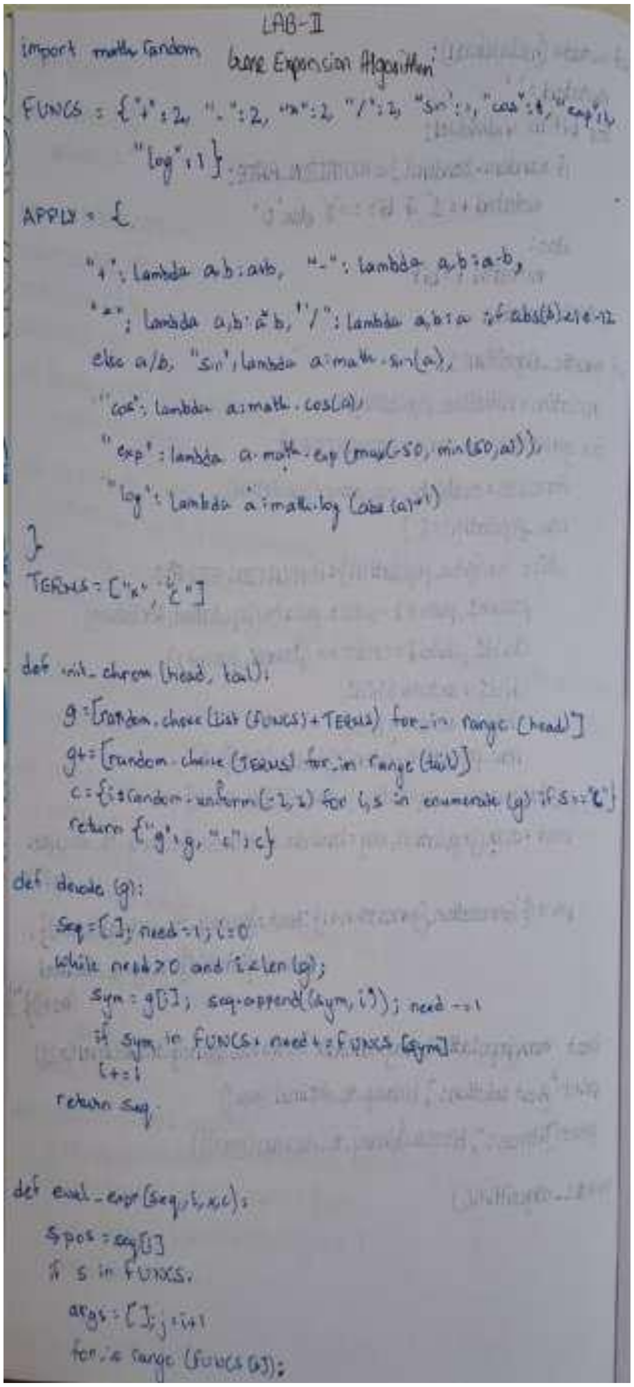
Lab 2

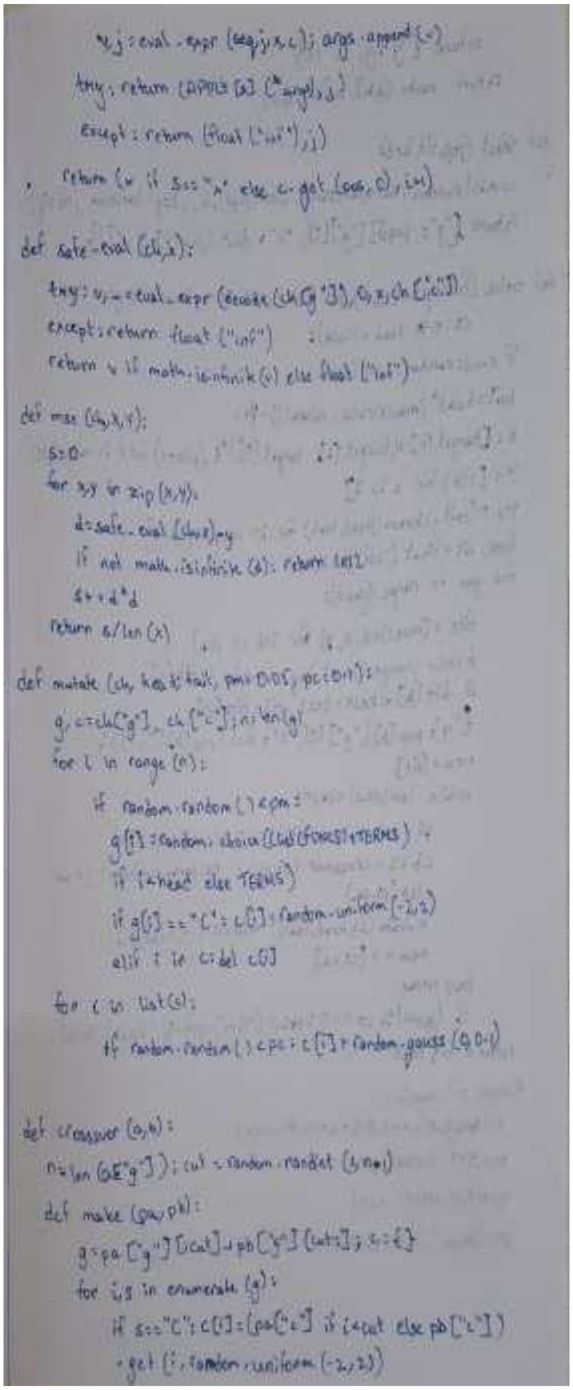
Gene Expression Algorithm



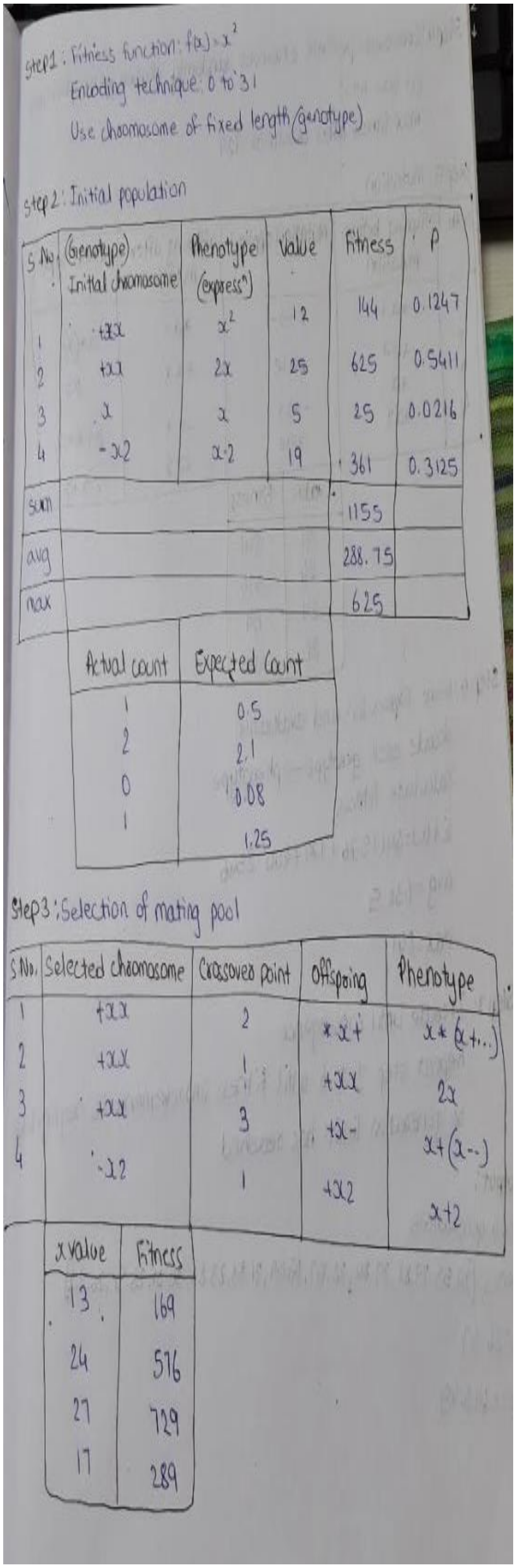
LAB-II

Gene Expension Algorithm

```
import math, random
FUNCS = {"+":2, "-":2, "*":2, "/":2, "sin":1, "cos":1, "exp":1,
        "log":1}
APPLY = {
    "+": lambda a,b: a+b,  "-": lambda a,b: a-b,
    "*": lambda a,b: a*b, "/": lambda a,b: a if abs(b)<1e-12
    else a/b, "sin": lambda a: math.sin(a),
    "cos": lambda a: math.cos(a),
    "exp": lambda a: math.exp(max(-50, min(50,a))),
    "log": lambda a: math.log(abs(a)+1)
}
TERMS = ["x", "C"]

def init_chrom(head, tail):
    g = [random.choice(list(FUNCS)+TERMS) for _ in range(head)]
    g += [random.choice(TERMS) for _ in range(tail)]
    c = {i: random.uniform(-2,2) for i,s in enumerate(g) if s=="C"}
    return {"g": g, "c": c}
def decode(g):
    seq=[]; need=1; i=0
    while need>0 and i<len(g):
        sym = g[i]; seq.append((sym, i)); need -= 1
        if sym in FUNCS: need += FUNCS[sym]
        i+=1
    return seq

def eval_expr(seq, i, x, c):
    s, pos = seq[i]
    if s in FUNCS:
        args = []; j = i+1
        for _ in range(FUNCS[s]):
```



```
            v, j = eval_expr(seq, j, x, c); args.append(v)
        try: return (APPLY[s](*args), j)
        except: return (float("inf"), j)
    return (x if s=="x" else c.get(pos, 0), i+1)

def safe_eval(ch, x):
    try: v, _ = eval_expr(decode(ch["g"]), 0, x, ch["c"])
    except: return float("inf")
    return v if math.isfinite(v) else float("inf")

def mse(ch, X, Y):
    s=0
    for x,y in zip(X,Y):
        d = safe_eval(ch,x)-y
        if not math.isfinite(d): return 1e12
        s += d*d
    return s/len(X)

def mutate(ch, head, tail, pm=0.05, pc=0.1):
    g, c = ch["g"], ch["c"]; n = len(g)
    for i in range(n):
        if random.random() < pm:
            g[i] = random.choice(list(FUNCS)+TERMS)
            if i<head else TERMS)
            if g[i]=="C": c[i] = random.uniform(-2,2)
            elif i in c: del c[i]
    for i in list(c):
        if random.random() < pc: c[i] + random.gauss(0, 0.1)

def crossover(a, b):
    n = len(a["g"]); cut = random.randint(1, n-1)
    def make(pa, pb):
        g = pa["g"][:cut] + pb["g"][cut:]; c = {}
        for i,s in enumerate(g):
            if s=="C": c[i] = (pa["c"] if i<cut else pb["c"])
            .get(i, random.uniform(-2,2))
        return {"g": g, "c": c}
    return make (a,b), make (b,a)

def select (pop, fit, k=3):
i   i=min(random. sample (range (len (pop)), k), key = lambda j:fit[j]\
    return {"g": pop[i] ["g"][:], "c": dict (pop [i] ["c"])}

def evolve (f, target =(-3,3), pts = 64, popn =100, head=10, gens =100
            cx: 0.7, seed = None):
    if seed: random : seed (seed)
    tail=head* (max(FUNCS . values()) - 1)+1
    X = [target [0] +(target [1] - target [0])*i /pts-1) for i in range(pts)
    y = [f(x) for x in X]
    pop = [init_chrom (head, tail) for_in range (popn)]
    best, fit = float ("inf"), None
    for gen in range (gens):
        fits = [mse (ind, x, y) for ind in pop]
        b=min (range (popn), key = lambda i: fits[i])
        if fits [b] < best: best, fit= fits [b],
        {"g": pop [b] ["g"] [:], "c": dict (pop [b] ["c"])}
        new = [fit]
        while len (new) < popn:
            p1 = select (pop, fits); p2 = select (pop, fits)
            c1, c2 = crossover (p1,p2) if random. random () < cx
            else (p1, p2)
            mutate (c1, head, tail); mutate (c2, head, tail)
            new + = [c1, c2]
        pop =new
        if (gen+1)% 20 = = 0: print ("Gen", gen+1, "Best", best)
    return fit, best

if_name_ = = "_main_":
    f = lambda x: x * * 3-0.5 * x+ math. sin(x)
    best, err = evolve (f, gens = 100)
    print (Best error: ", err)
    print ("Preds:", [safe_eval (best, x) for x in [-2, -1, 0, 1, 2]])
```



step1 : Fitness function: $f(x) = x^2$

Encoding technique: 0 to 31

Use chromosome of fixed length (genotype)

step 2 : Initial population

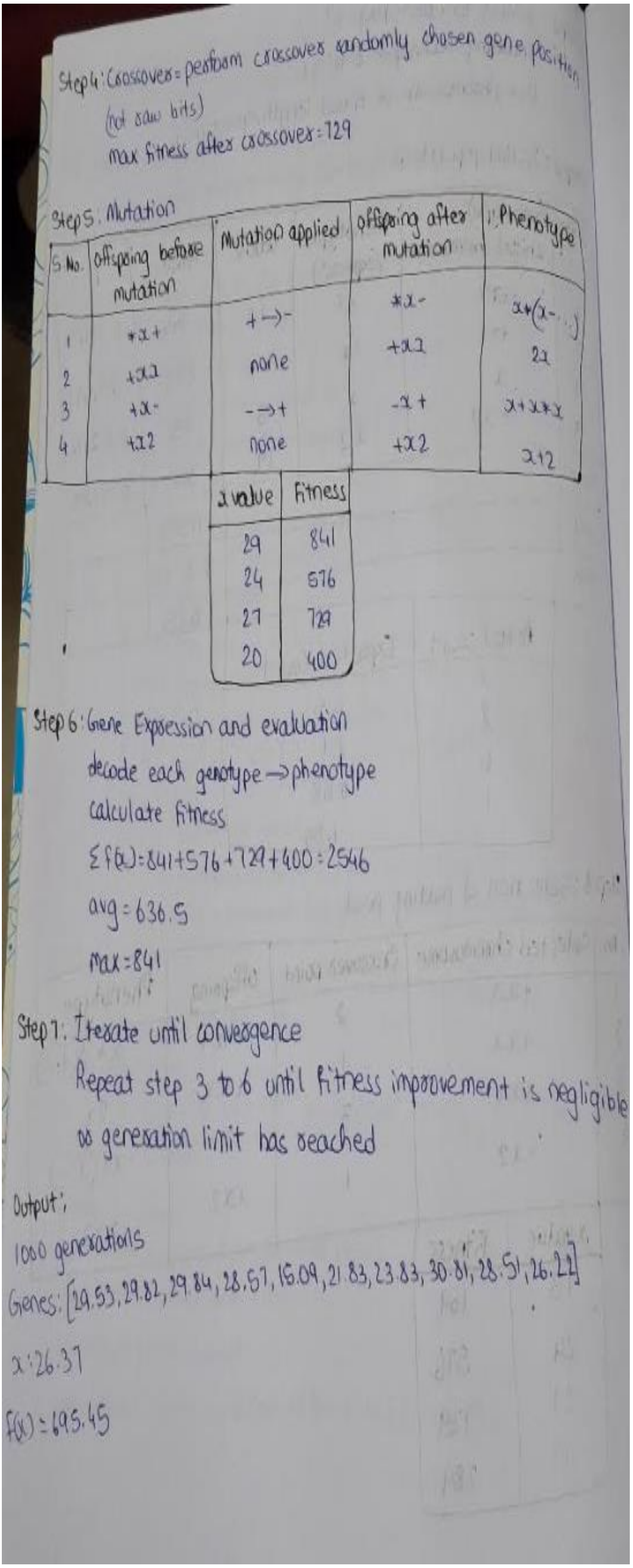
S.No.	(Genotype) Initial chromosome	Phenotype (expressⁿ)	Value	Fitness	P
1	+xx	x^2	12	144	0.1247
2	+xx	2x	25	625	0.5411
3	x	x	5	25	0.0216
4	-x2	x-2	19	361	0.3125
sum				1155	
avg				288.75	
max				625	

Actual count	Expected Count
1	0.5
2	2.1
0	0.08
1	1.25

Step3 : Selection of mating pool

S.No.	Selected chromosome	Crossover point	Offspring	Phenotype
1	+xx	2	*x+	x*(x+..)
2	+xx	1	+xx	2x
3	+xx	3	+x-	x+(x--)
4	-x2	1	+x2	x+2

x value	Fitness
13	169
24	576
27	729
17	289



Step4 : Crossover = perform crossover randomly chosen gene position (not raw bits)

max fitness after crossover = 729

Step5 : Mutation

S.No.	offspring before mutation	Mutation applied	offspring after mutation	Phenotype
1	*x+	+ → -	*x-	x*(x-...)
2	+xx	none	+xx	2x
3	+x-	- → +	-x+	x+x*x
4	+x2	none	+x2	x+2

x value	Fitness
29	841
24	576
27	729
20	400

Step 6 : Gene Expression and evaluation

decode each genotype → phenotype

calculate fitness

$\Sigma f(x) = 841 + 576 + 729 + 400 = 2546$

avg = 636.5

max = 841

Step 7 : Iterate until convergence

Repeat step 3 to 6 until fitness improvement is negligible or generation limit has reached

Output :

1000 generations

Genes: [29.53, 29.82, 29.84, 28.57, 15.09, 21.83, 23.83, 30.81, 28.51, 26.22]

x : 26.37

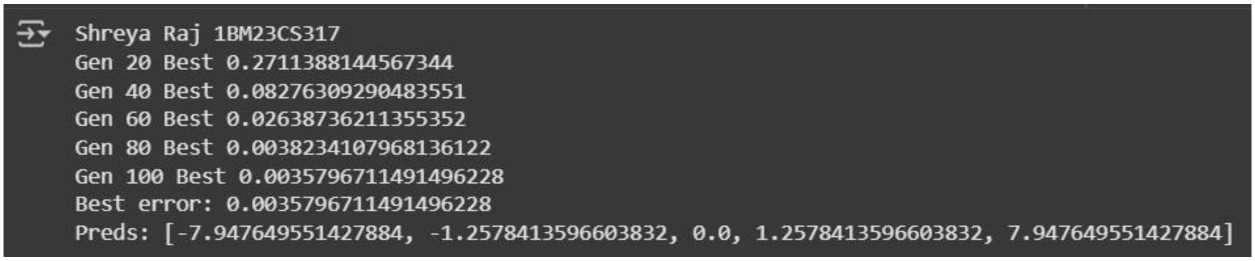
f(x) = 695.45

Code:

```
print("Shreya Raj 1BM23CS317")
import math, random

# --- Function set ---
FUNCS = {"+":2,"-":2,"*":2,"/":2,"sin":1,"cos":1,"exp":1,"log":1}
APPLY = {
    "+":lambda a,b:a+b, "-":lambda a,b:a-b, "*":lambda a,b:a*b,
    "/":lambda a,b:a if abs(b)<1e-12 else a/b,
    "sin":lambda a:math.sin(a), "cos":lambda a:math.cos(a),
    "exp":lambda a:math.exp(max(-50,min(50,a))),
    "log":lambda a:math.log(abs(a)+1)
}
TERMS=["x","C"]

def init_chrom(head,tail):
    g=[random.choice(list(FUNCS)+TERMS) for _ in range(head)]
    g+=[random.choice(TERMS) for _ in range(tail)]
    c={i:random.uniform(-2,2) for i,s in enumerate(g) if s=="C"}
    return {"g":g,"c":c}

def decode(g):
    seq=[];need=1;i=0
    while need>0 and i<len(g):
        sym=g[i];seq.append((sym,i));need-=1
        if sym in FUNCS: need+=FUNCS[sym]
        i+=1
    return seq

def eval_expr(seq,i,x,c):
    s,pos=seq[i]
    if s in FUNCS:
        args=[];j=i+1
        for _ in range(FUNCS[s]):
            v,j=eval_expr(seq,j,x,c);args.append(v)
        try:return (APPLY[s](*args),j)
        except: return (float("inf"),j)
    return (x if s=="x" else c.get(pos,0),i+1)

def safe_eval(ch,x):
    try:v,_=eval_expr(decode(ch["g"]),0,x,ch["c"])
    except:return float("inf")
    return v if math.isfinite(v) else float("inf")

def mse(ch,X,Y):
    s=0
    for x,y in zip(X,Y):
        d=safe_eval(ch,x)-y
        if not math.isfinite(d): return 1e12
        s+=d*d
    return s/len(X)
```

```
def mutate(ch,head,tail,pm=0.05,pc=0.1):
  g,c=ch["g"],ch["c"];n=len(g)
  for i in range(n):
    if random.random()<pm:
      g[i]=random.choice((list(FUNCS)+TERMS) if i<head else TERMS)
      if g[i]=="C":c[i]=random.uniform(-2,2)
      elif i in c:del c[i]
  for i in list(c):
    if random.random()<pc:c[i]+=random.gauss(0,0.1)

def crossover(a,b):
  n=len(a["g"]);cut=random.randint(1,n-1)
  def make(pa,pb):
    g=pa["g"][:cut]+pb["g"][cut:];c={}
    for i,s in enumerate(g):
      if s=="C":c[i]=(pa["c"] if i<cut else pb["c"]).get(i,random.uniform(-2,2))
    return {"g":g,"c":c}
  return make(a,b),make(b,a)

def select(pop,fit,k=3):
  i=min(random.sample(range(len(pop)),k),key=lambda j:fit[j])
  return {"g":pop[i]["g"][:],"c":dict(pop[i]["c"])}

def evolve(f,target=(-3,3),pts=64,popn=100,head=10,gens=100,cx=0.7,seed=None):
  if seed:random.seed(seed)
  tail=head*(max(FUNCS.values())-1)+1
  X=[target[0]+(target[1]-target[0])*i/(pts-1) for i in range(pts)]
  Y=[f(x) for x in X]
  pop=[init_chrom(head,tail) for _ in range(popn)]
  best,fit=float("inf"),None
  for gen in range(gens):
    fits=[mse(ind,X,Y) for ind in pop]
    b=min(range(popn),key=lambda i:fits[i])
    if fits[b]<best:best,fit=fits[b],{"g":pop[b]["g"][:],"c":dict(pop[b]["c"])}
    new=[fit]
    while len(new)<popn:
      p1=select(pop,fits);p2=select(pop,fits)
      c1,c2=crossover(p1,p2) if random.random()<cx else (p1,p2)
      mutate(c1,head,tail);mutate(c2,head,tail)
      new+=[c1,c2]
    pop=new
    if (gen+1)%20==0:print("Gen",gen+1,"Best",best)
  return fit,best

if __name__=="__main__":
  f=lambda x:x**3-0.5*x+math.sin(x)
  best,err=evolve(f,gens=100)
  print("Best error:",err)
  print("Preds:",[safe_eval(best,x) for x in [-2,-1,0,1,2]])
```

Output:



```
Shreya Raj 1BM23CS317
Gen 20 Best 0.2711388144567344
Gen 40 Best 0.08276309290483551
Gen 60 Best 0.02638736211355352
Gen 80 Best 0.0038234107968136122
Gen 100 Best 0.0035796711491496228
Best error: 0.0035796711491496228
Preds: [-7.947649551427884, -1.2578413596603832, 0.0, 1.2578413596603832, 7.947649551427884]
```