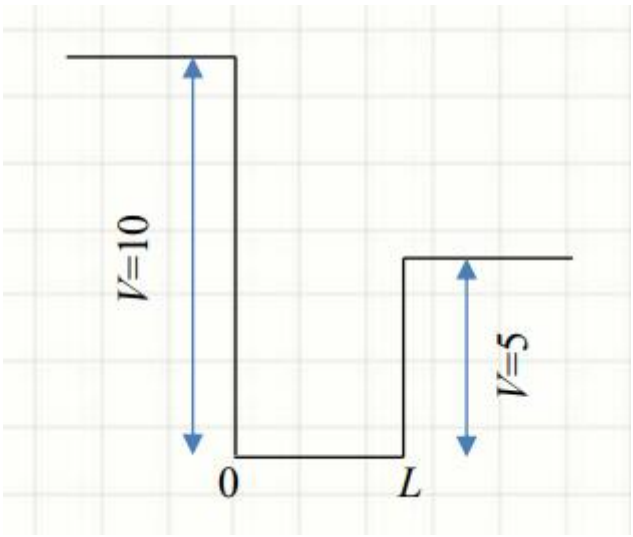
Question 4. Find up to three energy levels from the ground state of a particle trapped in a one-dimensional, asymmetric potential well as in the figure.



In [1]:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.integrate as integ
```

In [2]:

```
h=0.005
L = 1.0
t=np.arange(0,L,h)
```

In [3]:

```
#right side
def fr(y,t,E):
    x,v=y
    if t<L*0.5:
        U=0.0
    else:
        U=5.0
    return [v,2.0*(U-E)*x]
```

In [4]:

```
#left side
def fl(y,t,E):
    x,v=y
    if t<L*0.5:
        U=0.0
    else:
        U=10.0
    return [v,2.0*(U-E)*x]
```

In [5]:

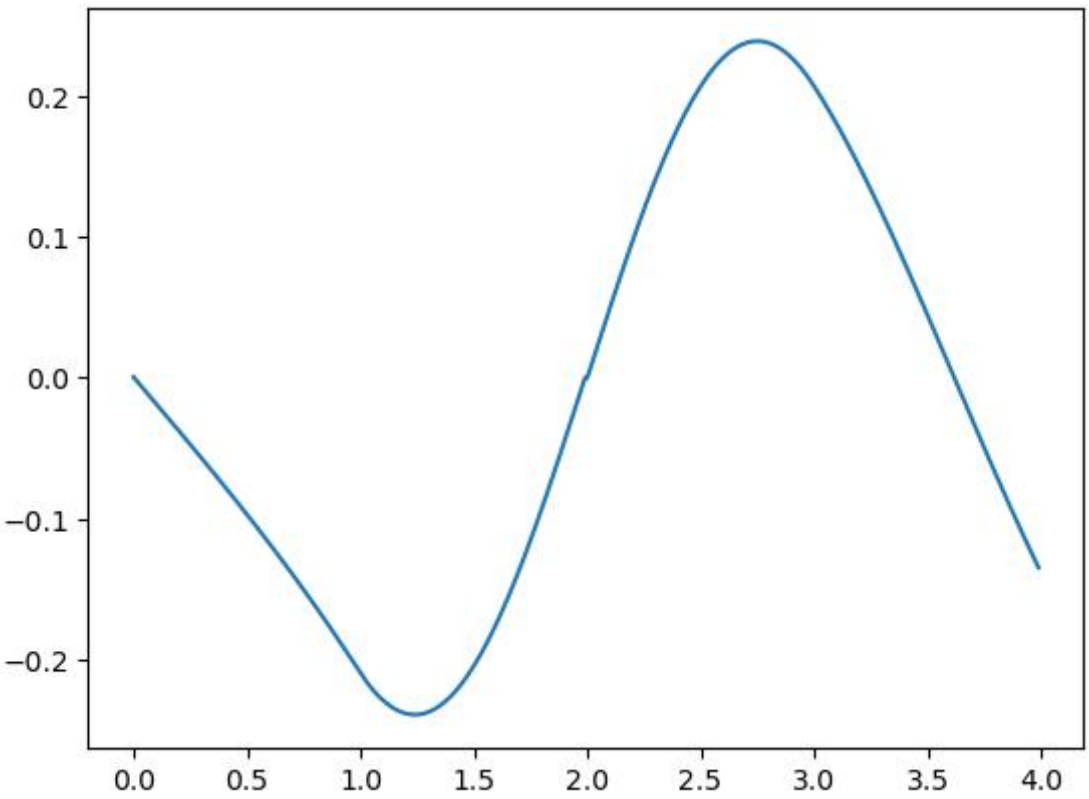
```
#initial condition for assymetricity
y0=[0.0,1.0]
```

By the potential which goes to the infinity, the wave function will go positive zero in infinity.Therefoer, if we find the energy which becomes negative, then the allowed energy will be between that energy and former energy.

ground state

In [10]:

```
E = 0
h = 1e-2
while True :
    solr = integ.odeint(fr,y0,t,args=(E,))
    soll = integ.odeint(fl,y0,t,args=(E,))
    soll = soll[::-1]*(-1)
    if soll[0,0]>0 and solr[-1,0] < 0:
        sol = np.concatenate((soll, solr), axis=0)
        plt.plot(np.arange(0,L*4,h),sol[:,0]); plt.show()
        break
    sol_before = sol
    E_b = E
    E = E + h
```



In [12]:

```
E_b
```

Out[12]:

8.759999999999858

In [13]:

```
E
```

Out[13]:

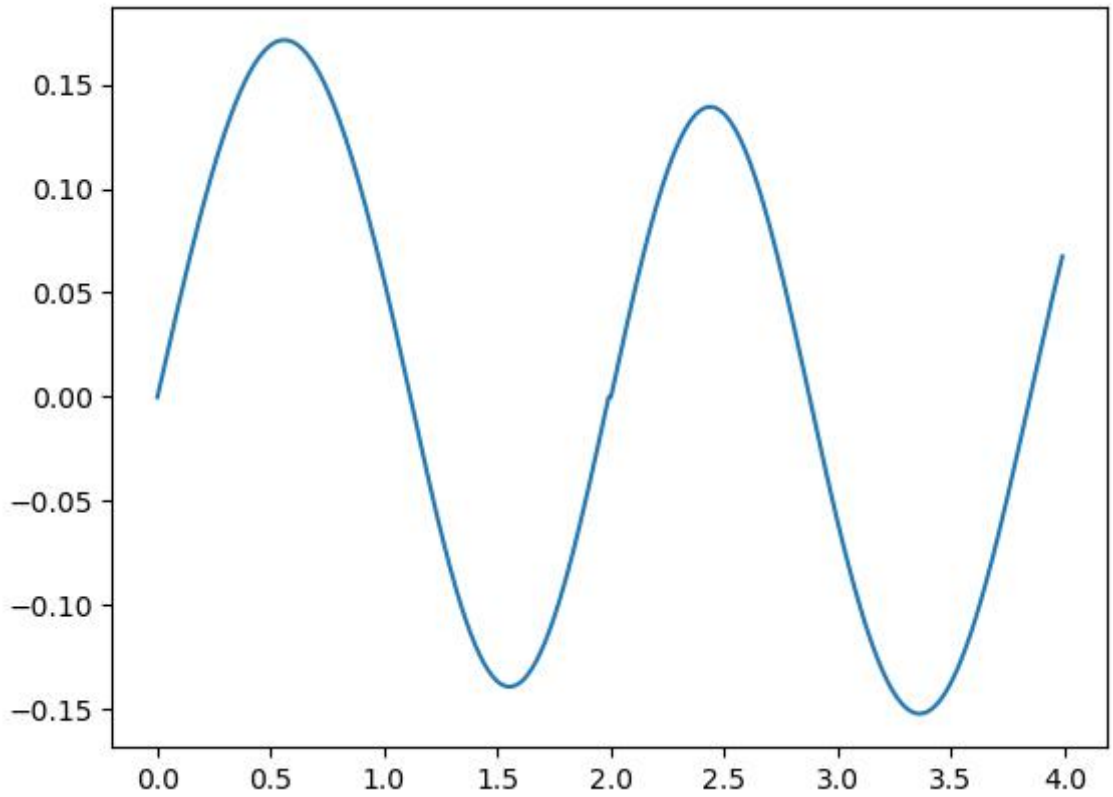
8.769999999999857

Ground energy is between 8.77 and 8.77

first exited state

In [16]:

```
E = 8.8
h = 1e-2
while True :
    solr = integ.odeint(fr,y0,t,args=(E,))
    soll = integ.odeint(fl,y0,t,args=(E,))
    soll = soll[::-1]*(-1)
    if soll[0,0]<0 and solr[-1,0] > 0:
        sol = np.concatenate((soll, solr), axis=0)
        plt.plot(np.arange(0,L*4,h),sol[:,0]); plt.show()
        break
    sol_before = sol
    E_b = E
    E = E + h
```



In [17]:

```
E
```

Out[17]:

25.790000000001378

In [18]:

```
E_b
```

Out[18]:

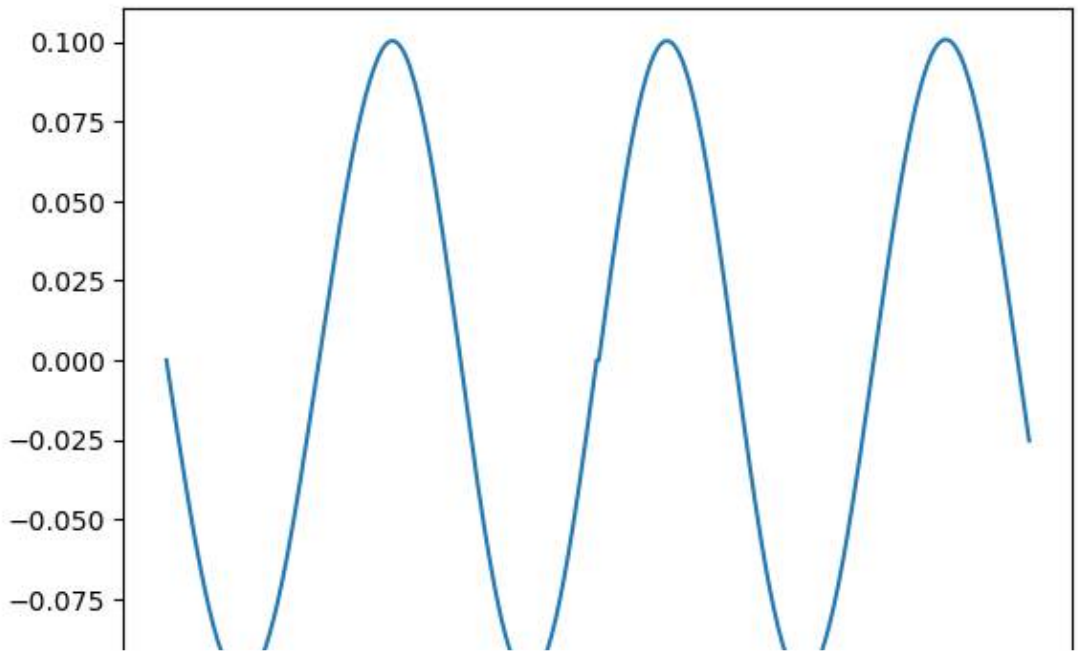
25.780000000001376

allowed energy is between 25.78 and 25.79

second excited state

In [20]:

```
E = 26
h = 1e-2
while True :
    solr = integ.odeint(fr,y0,t,args=(E,))
    soll = integ.odeint(fl,y0,t,args=(E,))
    soll = soll[::-1]*(-1)
    if soll[0,0]>0 and solr[-1,0] < 0:
        sol = np.concatenate((soll, solr), axis=0)
        plt.plot(np.arange(0,L*4,h),sol[:,0]); plt.show()
        break
    sol_before = sol
    E_b = E
    E = E + h
```



In [21]:

```
E
```

Out[21]:

49.68999999999742

In [22]:

```
E_b
```

Out[22]:

49.67999999999742

Allowed energy is between 49.67 and 49.68