

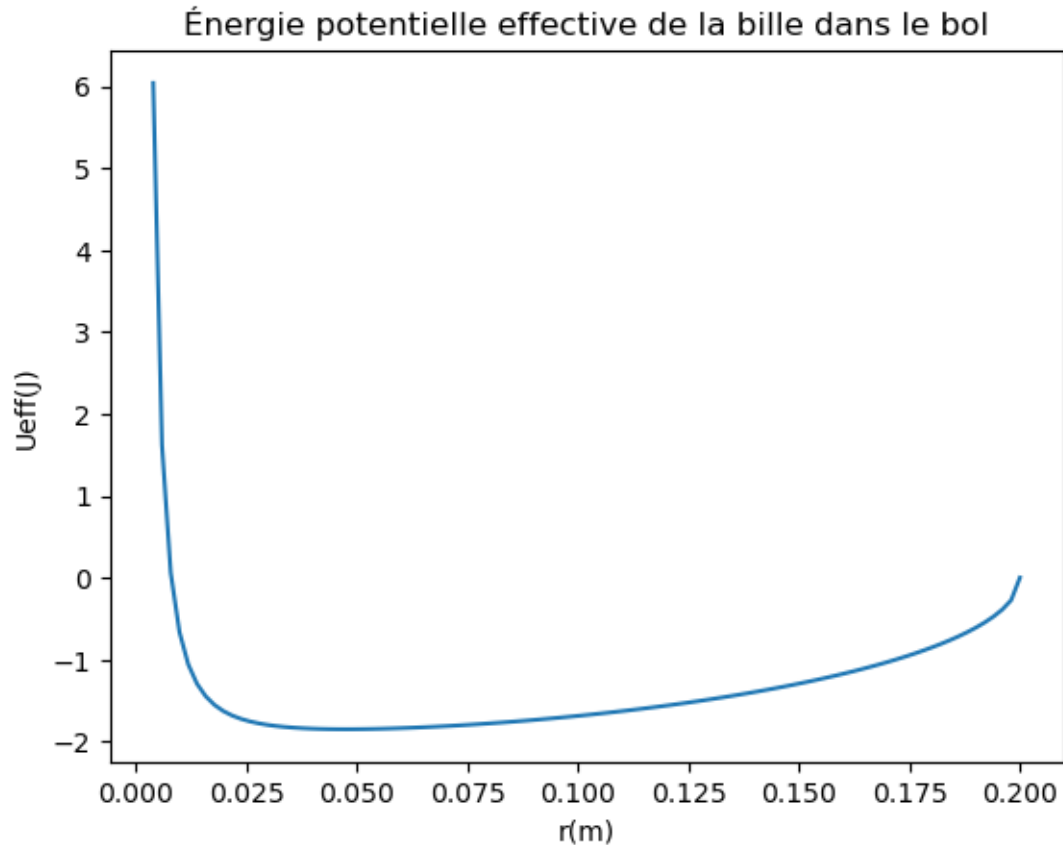
## Bille dans un bol

```
[2]: import numpy as np
import matplotlib.pyplot as plt
from scipy.integrate import odeint
```

```
[22]: r0=8e-2
v0=10e-2
dthetadt0=v0/r0
C=r0**2*dthetadt0
R=20e-2
g=9.8
```

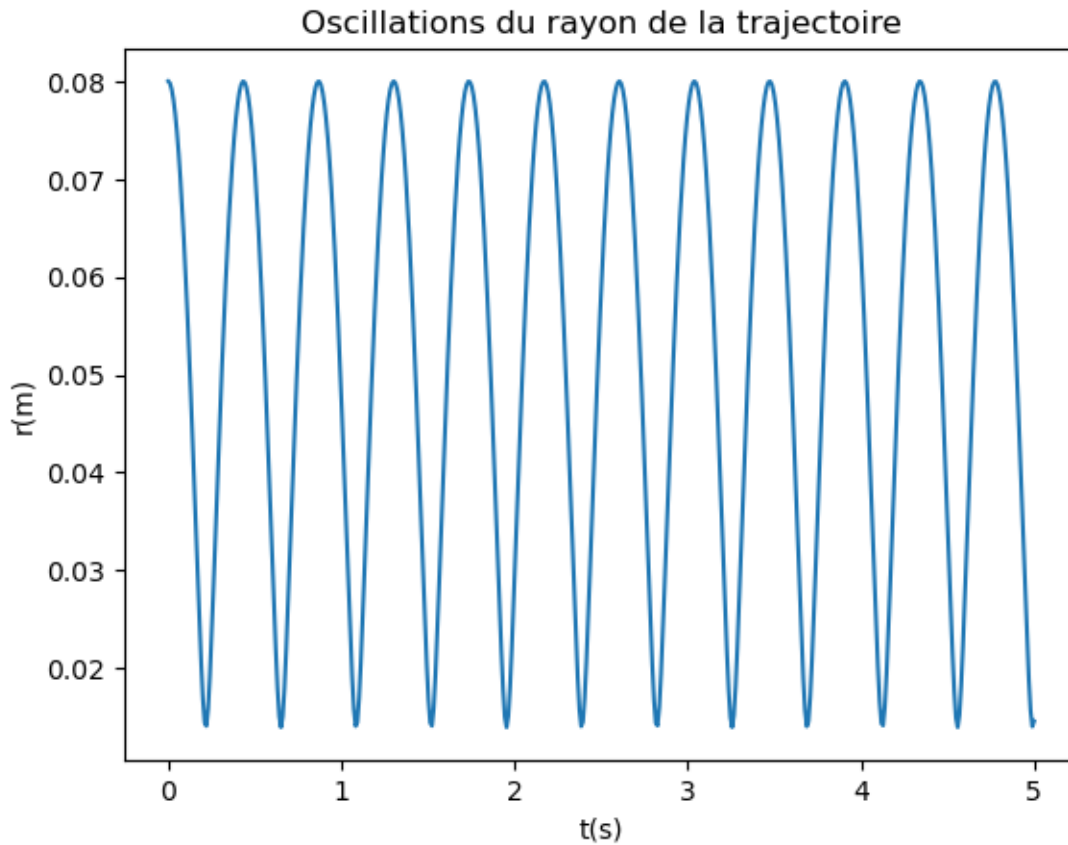
On a  $U_{eff}(r) = \frac{mC^2}{2r^2} - m.g.\sqrt{R^2 - r^2}$

```
[49]: def u_eff(r):
    return C**2/2/r**2-g*np.sqrt(R**2-r**2)
tab_r=np.linspace(0.02*R,R,100)
tab_ueff=u_eff(tab_r)
plt.figure()
plt.plot(tab_r,tab_ueff)
plt.xlabel("r(m)")
plt.ylabel("Ueff(J)")
plt.title("Énergie potentielle effective de la bille dans le bol")
plt.show()
```



$$\ddot{r} = \frac{C^2}{r^3} - \frac{gr}{\sqrt{R^2 - r^2}}$$

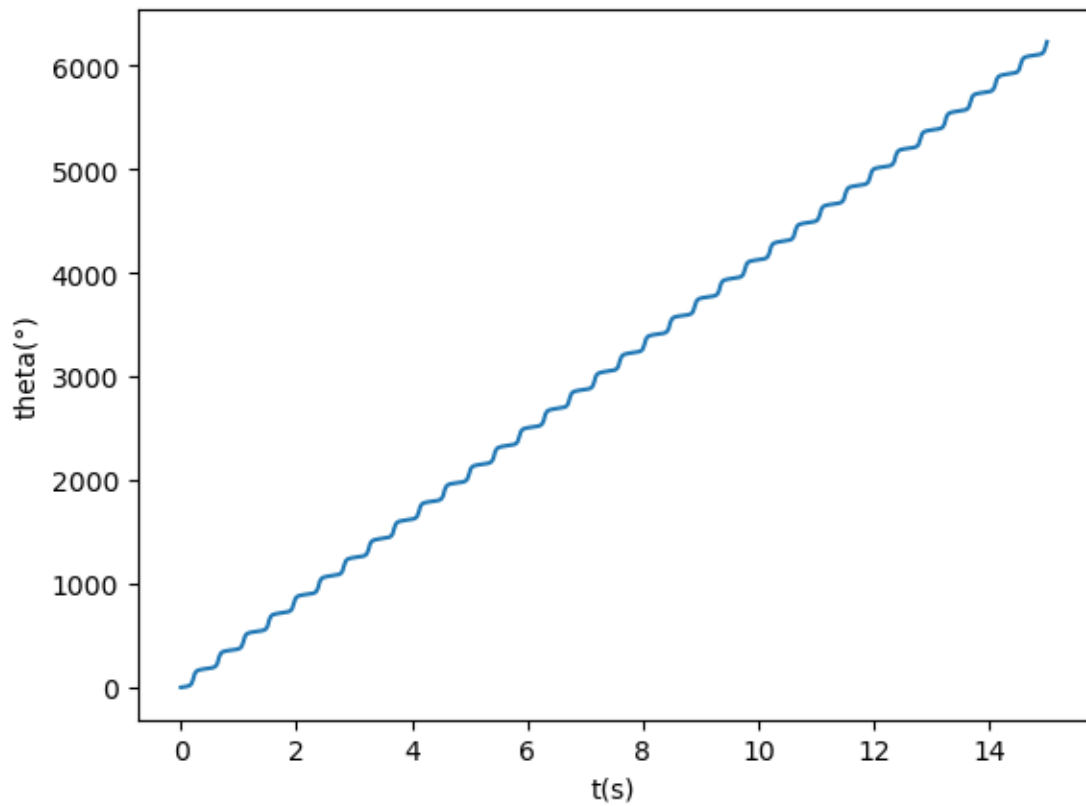
```
[24]: def derivee(inconnues,t):
    r=inconnues[0]
    drdt=inconnues[1]
    ddrdt=C**2/r**3-g*r/np.sqrt(R**2-r**2)
    return [drdt,ddrdt]
ci=[r0,0]
tab_t=np.linspace(0,5,500)
sol=odeint(derivee,ci,tab_t)
tab_r=sol[:,0]
plt.figure()
plt.plot(tab_t,tab_r)
plt.xlabel("t(s)")
plt.ylabel("r(m)")
plt.title("Oscillations du rayon de la trajectoire")
plt.show()
```



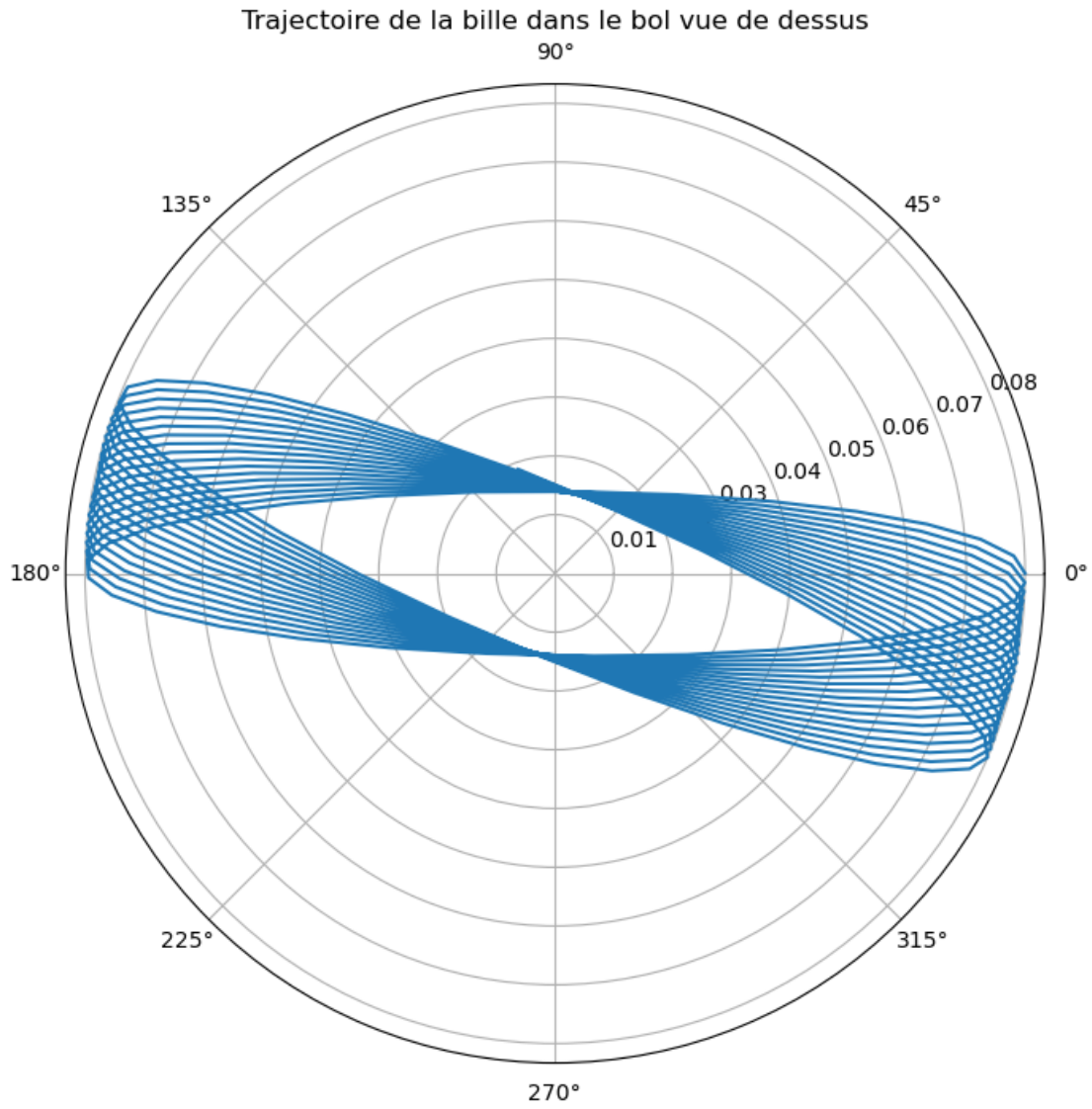
$$\dot{\theta} = \frac{C}{r^2}$$

```
[60]: r0=8e-2
v0=10e-2
dthetadt0=v0/r0
C=r0**2*dthetadt0
def derivee(inconnues,t):
    r=inconnues[0]
    drdt=inconnues[1]
    theta=inconnues[2]
    ddrdt=C**2/r**3-g*r/np.sqrt(R**2-r**2)
    dthetadt=C/r**2
    return [drdt,ddrdtt,dthetadt]
ci=[r0,0,0]
tab_t=np.linspace(0,15,500)
sol=odeint(derivee,ci,tab_t)
tab_r=sol[:,0]
tab_theta=sol[:,2]
plt.figure()
plt.plot(tab_t,tab_theta*180/np.pi)
```

```
plt.xlabel("t(s)")
plt.ylabel("theta(°)")
plt.show()
```

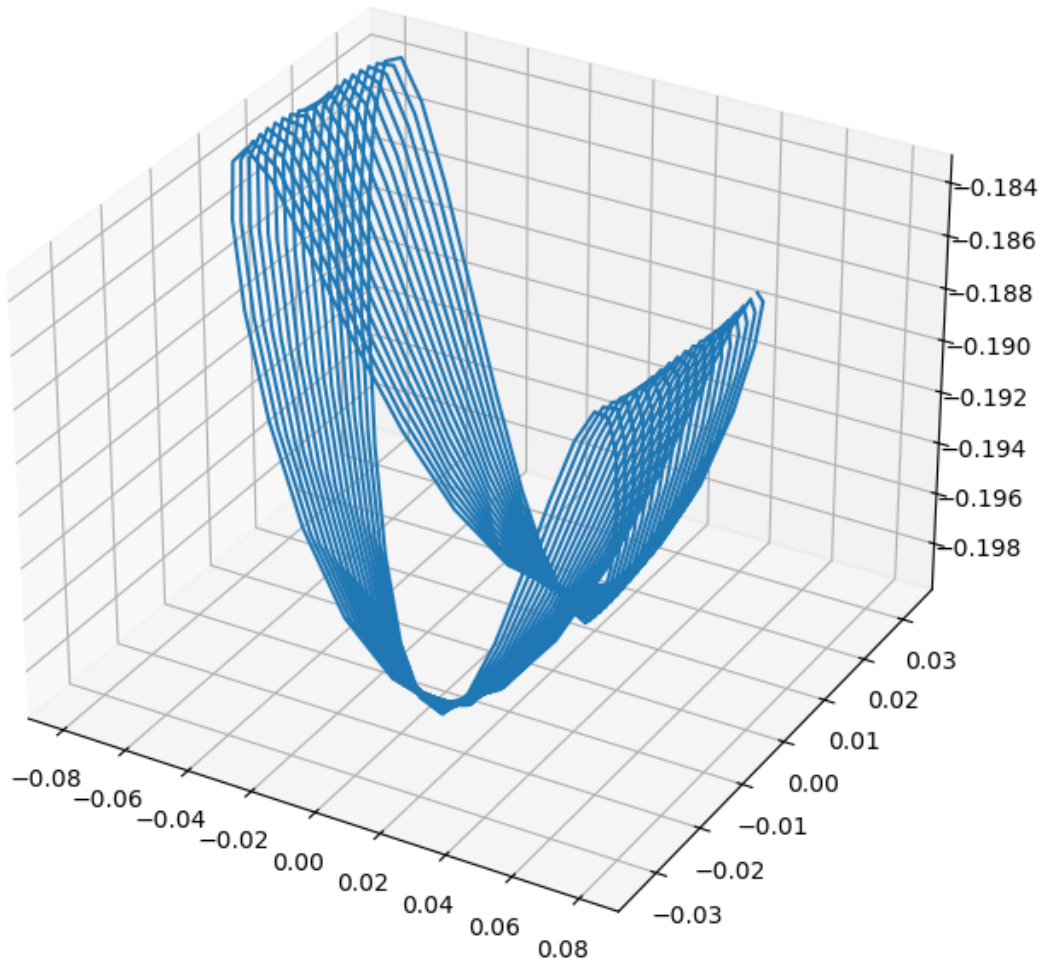


```
[61]: plt.figure(figsize=(8,8))
plt.polar(tab_theta,tab_r)
plt.title("Trajectoire de la bille dans le bol vue de dessus")
plt.show()
```



```
[62]: plt.figure(figsize=(8,8)).add_subplot(projection='3d')
tab_x=tab_r*np.cos(tab_theta)
tab_y=tab_r*np.sin(tab_theta)
tab_z=-np.sqrt(R**2-tab_r**2)
plt.plot(tab_x,tab_y,tab_z)
plt.title("Trajectoire de la bille dans le bol en 3D")
plt.show()
```

### Trajectoire de la bille dans le bol en 3D



[ ]:

[ ]: