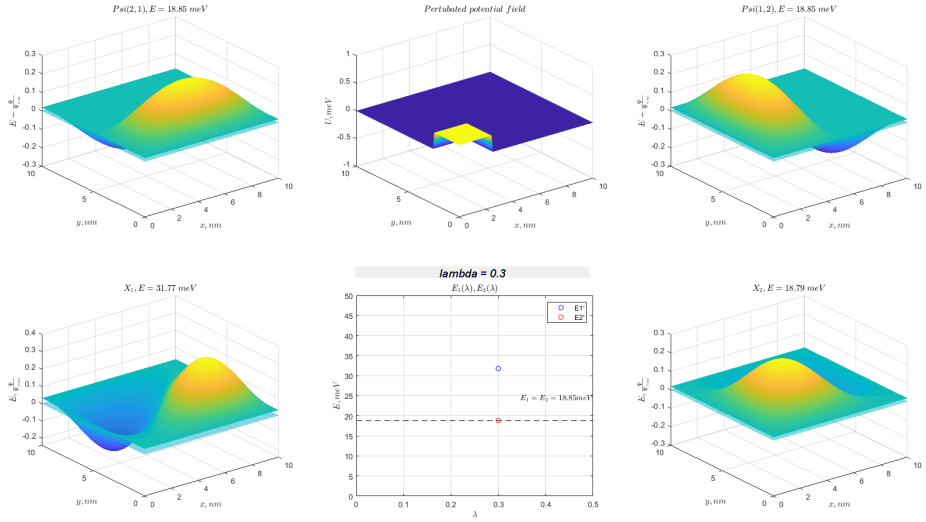
```
close all
clear
clc

fig=figure('Name','Method of variations','NumberTitle','off');
fig.Units='normalized';
fig.Position=[1 0 1 1];

lmbd=0.3;
%defining constants
hbar=1.0546e-34;
m0=9.1e-31;
e=1.6e-19;

%forming a task
L=1e-8;                         %width of structure
Np=100;                         %amount of steps
x=linspace(0,L, Np);            %creating a 'x-axis'
dx=x(2)-x(1);    dy=dx;         %definig a primive step
y=x';                           %creating a 'y-axis'
[X,Y]=meshgrid(x,y);            %creating a 2d-sapce

%defining potential feild and perubation
U=zeros(Np);
Upetr=lmbd*e*heaviside(-x+L/4).*heaviside(-y+L/4);

%defining wave functions for quantumm well
px=@(n,x)sqrt(2/L).*sin(pi*n*x/L);
py=@(m,y)sqrt(2/L).*sin(pi*m*y/L);
p=@(n,m,x,y)px(n,x).*py(m,y);
E=@(n,m)pi^2*hbar^2/(2*m0*L^2)*(n^2+m^2);

%set n=1 and m=2 as it is degenerated w/ n=2 and m=1
Psi1=p(1,2,X,Y);
E1=E(1,2);
Psi2=p(2,1,X,Y);
E2=E(2,1);

%Finding an amendment to Energy
%we know that states 2:1 and 1:2 are degenerated and have same energy
%that becomes unequal after petrubation

%Vab=<Psia|Upetr|Psib>; effect of eptrubation
V11=sum(sum(Psi1'.*Upetr.*Psi1,2)*dx,1)*dy;
V12=sum(sum(Psi1'.*Upetr.*Psi2,2)*dx,1)*dy;
V21=sum(sum(Psi2'.*Upetr.*Psi1,2)*dx,1)*dy;
V22=sum(sum(Psi2'.*Upetr.*Psi2,2)*dx,1)*dy;
%as we can see all of them have some non-zero value, but we want some
 to be

%solving a task to find new 'good' eigfunctions
M=[V11, V12; V21,V22];
```

```
[ab,de]=eig(M);
de=diag(de);%energeis for 'good' states

%new 'good' eigfunctions
%Xi=ab*[Psi1;Psi2];
if(de(1)>de(2))
    Xi1=ab(1,1)*Psi1+ab(1,2)*Psi2;
    Xi2=ab(2,1)*Psi1+ab(2,2)*Psi2;
else
    Xi2=ab(1,1)*Psi1+ab(1,2)*Psi2;
    Xi1=ab(2,1)*Psi1+ab(2,2)*Psi2;
    temp=de(1);
    de(1)=de(2);
    de(2)=temp;
end

%visualization
%(2;1)initial state
subplot(2,3,1)
Amp=max(max(Psi1));
hold off
surf(X*1e9, Y*1e9, U/e,'FaceAlpha',0.5)
hold on;
surf(X*1e9, Y*1e9,E1/e+0.25*Psi1/Amp);
surf(X*1e9, Y*1e9,E1*ones(Np)/e);
xlabel('$x,nm$', 'Interpreter', 'latex');
ylabel('$y,nm$', 'Interpreter', 'latex');
zlabel('$E+{\Psi\over\Psi_{max}}$', 'Interpreter', 'latex');
title(sprintf('$Psi(2,1),E=%2.2f$ $meV$',E1/
e*1000), 'Interpreter', 'latex');
grid on;
shading interp;

%force feild
subplot(2,3,2)
hold off
surf(X*1e9, Y*1e9, (U+Upetr)/e)
hold on;
xlabel('$x,nm$', 'Interpreter', 'latex');
ylabel('$y,nm$', 'Interpreter', 'latex');
zlabel('$U, meV$', 'Interpreter', 'latex');
title('$Pertubated$ $potential$ $field$', 'Interpreter', 'latex');
grid on;
shading interp;
zlim([-1 1])

%(1;2)initial state
subplot(2,3,3)
hold off
surf(X*1e9, Y*1e9, U/e,'FaceAlpha',0.5)
hold on;
surf(X*1e9, Y*1e9,E2/e+0.25*Psi2/Amp);
surf(X*1e9, Y*1e9,E2*ones(Np)/e);
xlabel('$x,nm$', 'Interpreter', 'latex');
```

```
ylabel('$y,nm$', 'Interpreter', 'latex');
zlabel('$E+{\Psi\over\Psi_{max}}$', 'Interpreter', 'latex');
title(sprintf('$Psi(1,2),E=%2.2f$ $meV$',E2/
e*1000), 'Interpreter', 'latex');
grid on;
shading interp;

%1 petr state, Xi1
subplot(2,3,4)
set(0,'defaulttextInterpreter','latex')
hold off
surf(X*1e9, Y*1e9, (U)/e,'FaceAlpha',0.5)
hold on;
surf(X*1e9, Y*1e9,(E1+de(1))/e+0.25*Xi1/Amp);
% surf(X*1e9, Y*1e9,E1*ones(Np)/e);
xlabel('$x,nm$', 'Interpreter', 'latex');
ylabel('$y,nm$', 'Interpreter', 'latex');
zlabel('$E,{\Psi\over\Psi_{max}}$', 'Interpreter', 'latex');
title(sprintf('$X_1,E=%2.2f$ $meV$',(E1+de(1))/
e*1000), 'Interpreter', 'latex');
grid on;
shading interp;

%dependences E1(lmbd) and E2(lmbd)
subplot(2,3,5)
LMBD=linspace(0,0.5, Np);
plot(LMBD,ones(1,Np)*E1/e*1000,'--k','HandleVisibility','off')
hold on
plot(lmbd,(E1+de(1))/e*1000,'ob')
plot(lmbd,(E2+de(2))/e*1000,'or')
xlabel('$\lambda$', 'Interpreter', 'latex');
ylabel('$E,meV$', 'Interpreter', 'latex');
title('$E_1(\lambda),E_2(\lambda)$', 'Interpreter', 'latex');
text(0.5,5+E1/e*1000, sprintf('$E_1 = E_2 = %2.2f meV$',E1/e*1e3),...

  'Interpreter','latex','HorizontalAlignment','right','VerticalAlignment','baselin
legend("E1'","E2'")
grid on;
ylim([0 0.05]*1000)
xlim([0 0.5])

%2 petr state,%1 petr state, Xi1
subplot(2,3,6)
hold off
surf(X*1e9, Y*1e9, (U)/e,'FaceAlpha',0.5)
hold on;
surf(X*1e9, Y*1e9,(E2+de(2))/e+0.25*Xi2/Amp);
% surf(X*1e9, Y*1e9,E2*ones(Np)/e);
xlabel('$x,nm$', 'Interpreter', 'latex');
ylabel('$y,nm$', 'Interpreter', 'latex');
zlabel('$E,{\Psi\over\Psi_{max}}$', 'Interpreter', 'latex');
title(sprintf('$X_2,E=%2.2f$ $meV$',(E2+de(2))/
e*1000), 'Interpreter', 'latex');
grid on;
```

```
shading interp;

%interfacing lambda-value
Lambda=uicontrol('style','text','String',['lambda = ',
 num2str(lmbd)],...

  'FontSize',14,'FontAngle','italic','HorizontalAlignment','center');
Lambda.Units='normalized';
Lambda.Position=[0.41 0.48 0.21 0.02];
```



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