PYL556 Quantum Mechanics II

Problem No. 3 [Group 6]

LANDAU-ZENER PROBLEM WITH HARMONIC COUPLING

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The Problem

We have been given a two level quantum system in which hamiltonian of the system is varying with time, such that the energy separation of the two states is a function of time. Dynamics of such time-independent system is given by time-dependent Schrodinger equation of the form

$$i\hbar\frac{\partial}{\partial t}|\Psi\rangle = \hat{H}(t)|\Psi\rangle$$

It has a similar description of that standard Landau Zener problem but with different perturbation term. Hamilton of the system is given as

$$\hat{H}(t) = A(t)\hat{\sigma}_z + B(t)\hat{\sigma}_x$$

(where σz and σx are pauli matrices)

$$A(t) = \mathbf{v}t/2$$

$$B(t) = \mathbf{g}\cos(\mathbf{\Omega}t + \Phi)$$

(**g**, **Ω** and **v** are the variable quantities)

It is given that the system starts at t=−∞ in the lower energy eigenstate.

Now we numerically integrate the time dependent schrodinger equation by converting it into a difference-equation and solving it using the Runge-Kutta method in the large time limit and calculated transition probability of remaining in the same (ground state) state after long time.

ROADMAP

STEP 1

Finding & Plotting the Energy Eigenvalues

STEP 2

Invoking the RK-4 Method to find the time evolutoin of Ψ

STEP 3

Normalising the wavefunction Ψ

STEP 4

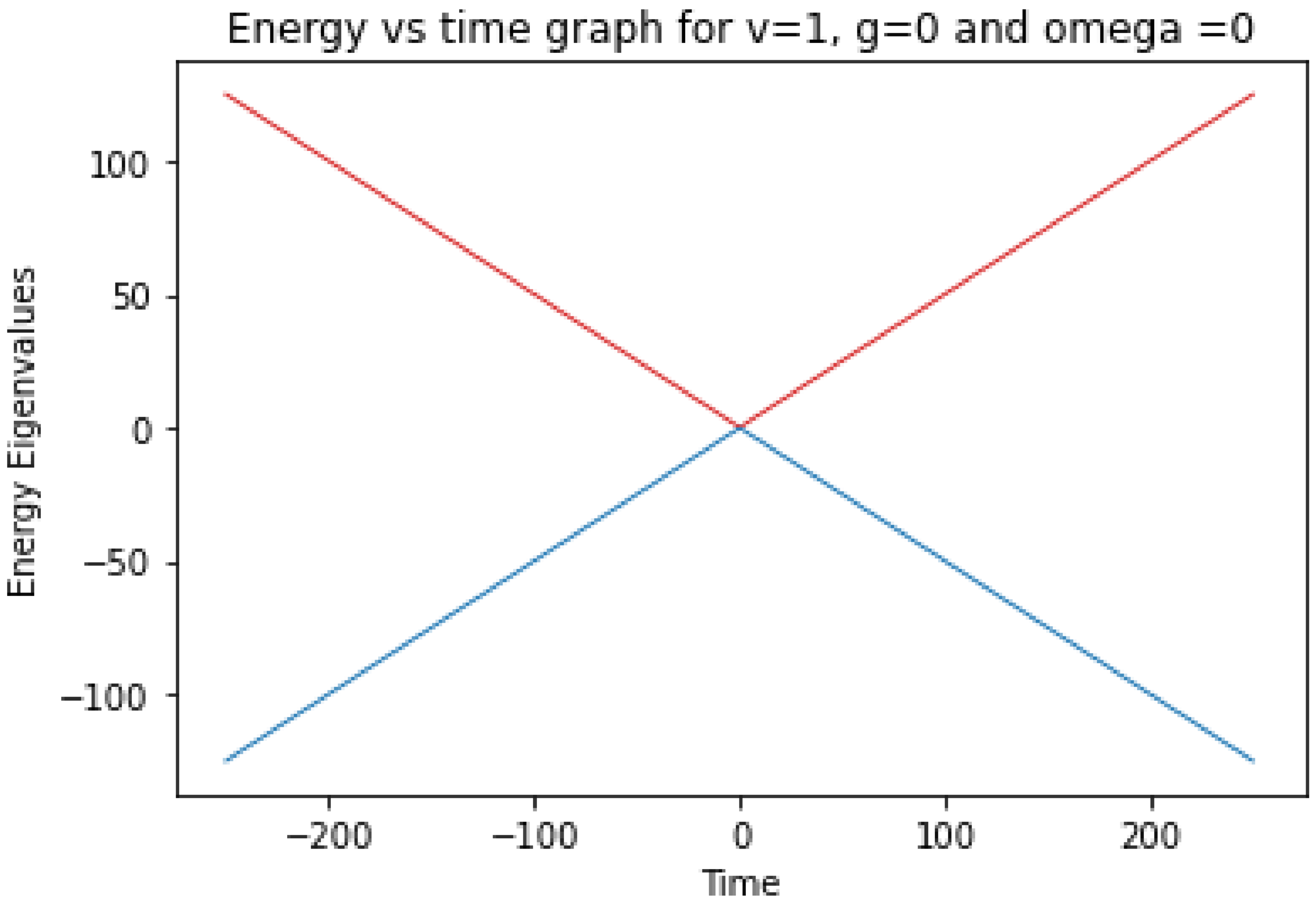
Plotting the transition probability of ground state

STEP 5

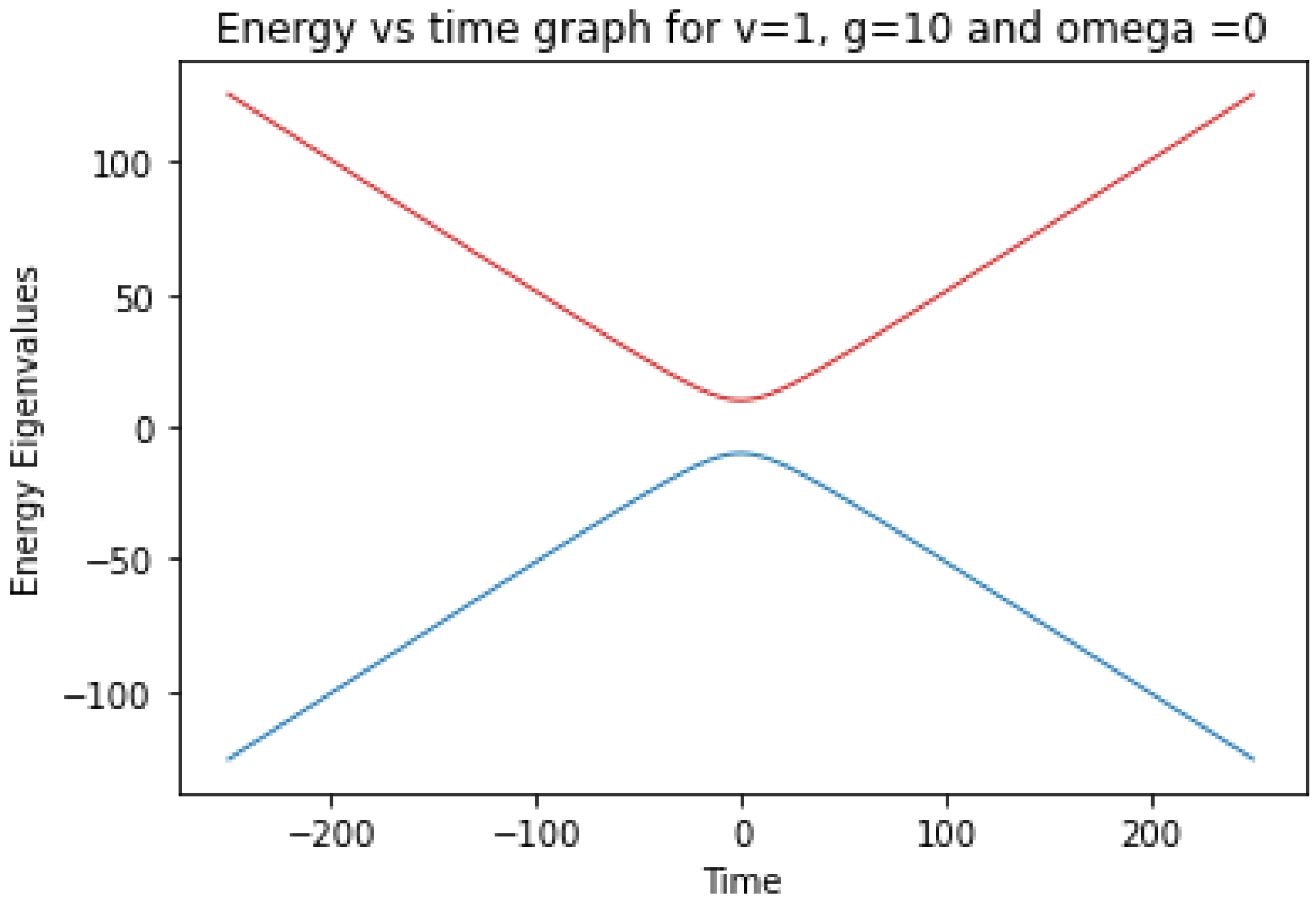
Comparison with standard Landau-Zener

Expected Plots for Energy Eigenvalues

With No Perturbation



With Constant Perturbation



Energy Eigenvalues

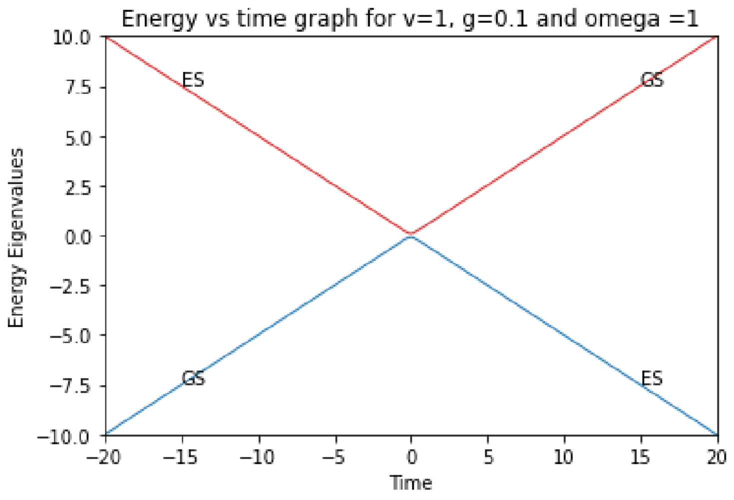
v=1

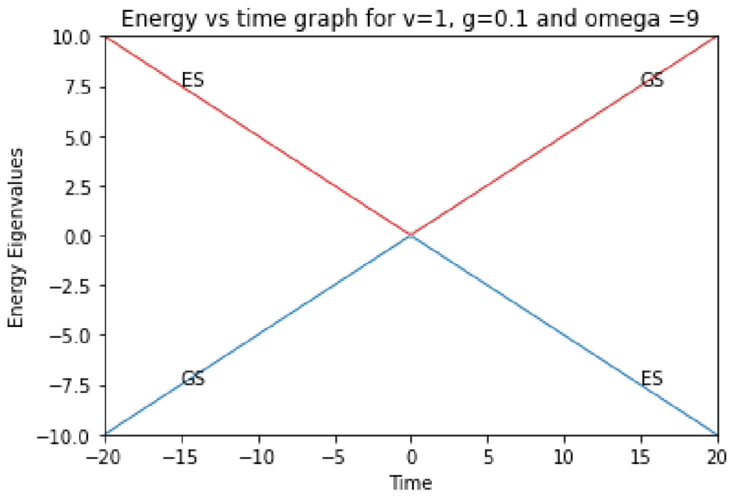
Ω=1 **Ω=9**

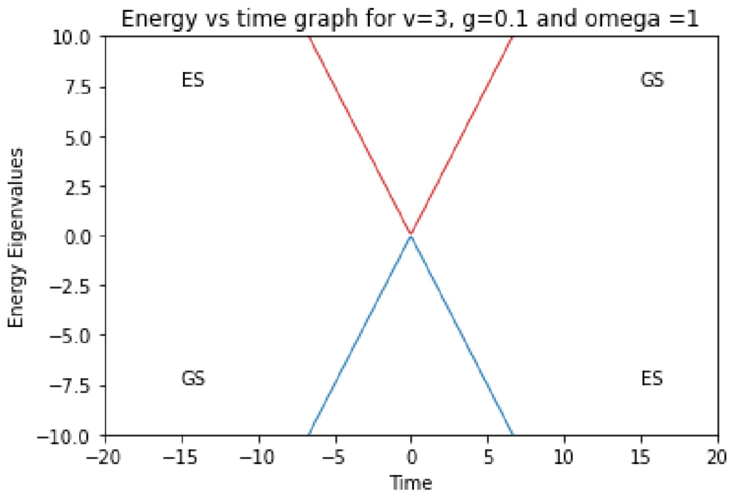
v=3

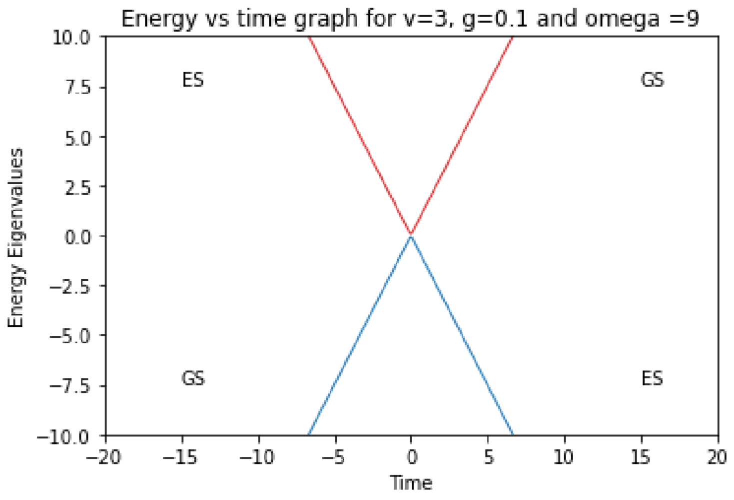
Ω=1 **Ω=9**

g=0.1

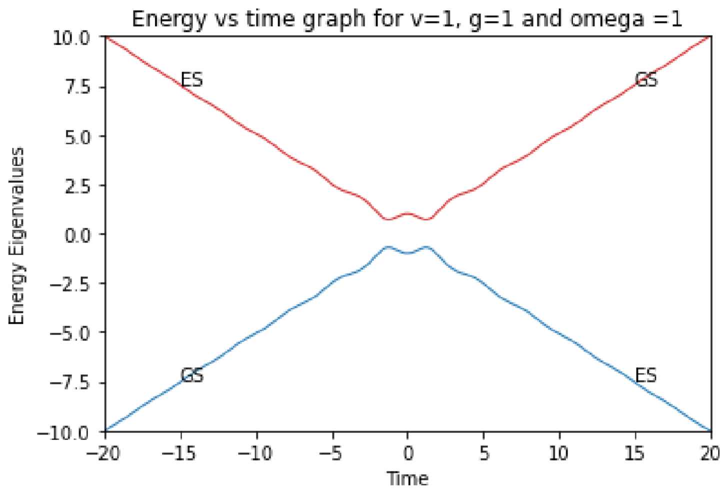


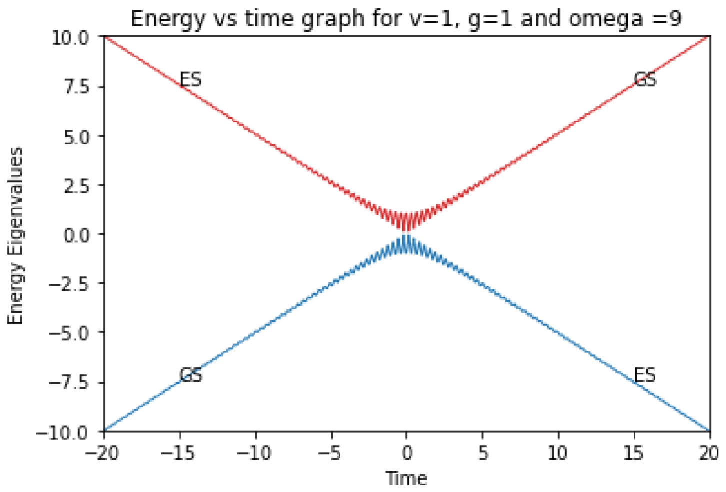


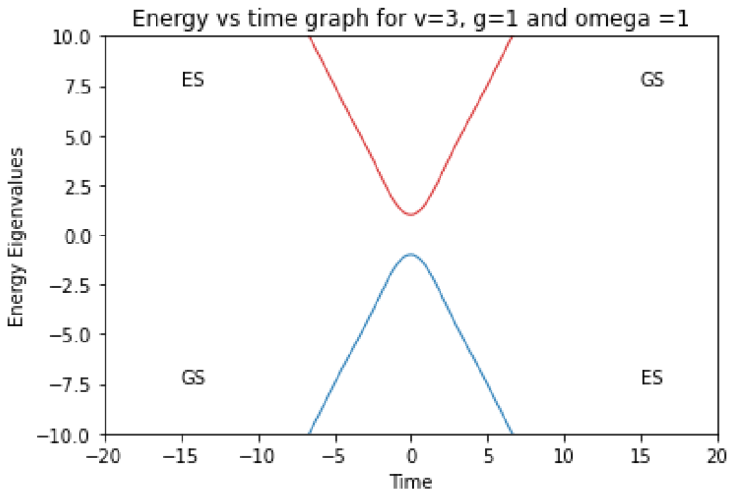


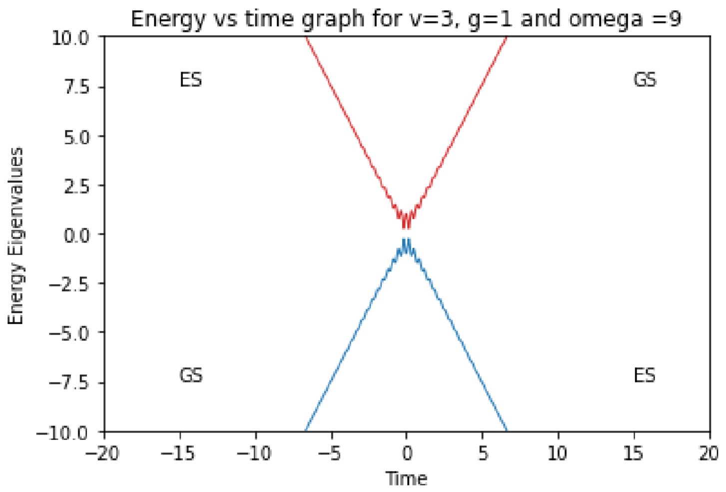


g=1

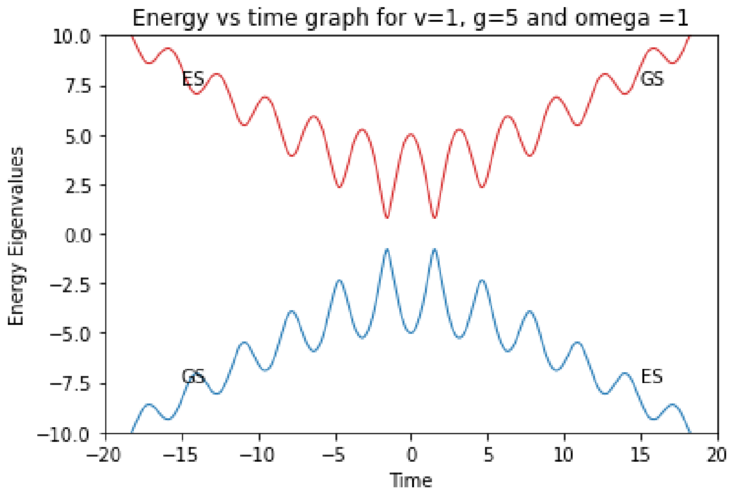


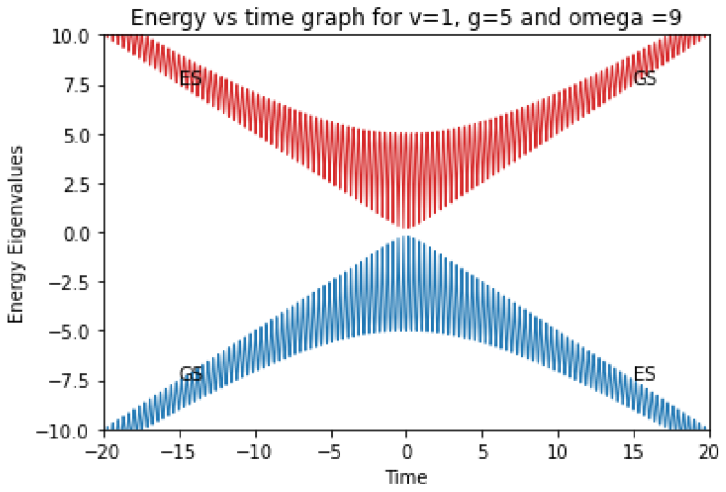


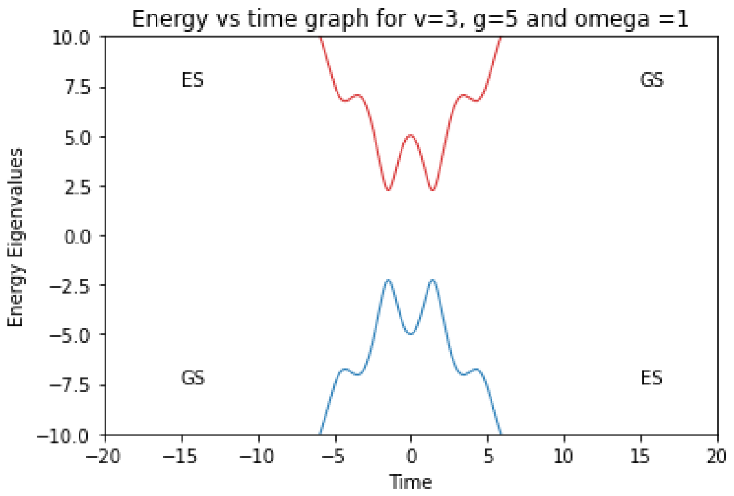


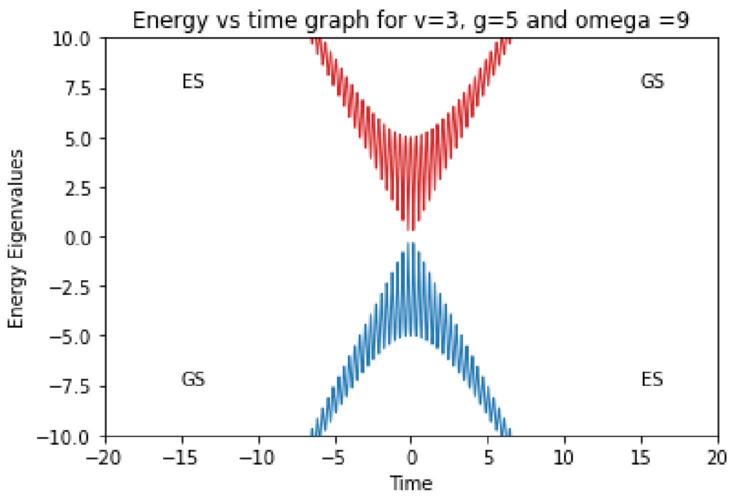


g=5









Transition Probability

Let us use our perturbation theory to calculate the probability P(t) of transition from $|0\rangle$ to $|t\rangle$, at time t, under the effect of the perturbation B(t)

The initial state at $t=-\infty$ is given as

$$|\Psi(-\infty)\rangle = |0\rangle \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

=

At any time t our wave-function will be

$$|\Psi(t)\rangle = |t\rangle = \begin{bmatrix} C_1 \\ C_2 \end{bmatrix}$$

Our transition prob. amplitude will be $\langle t|0\rangle$ and probability will $|\langle t|0\rangle|^2$

$$i\hbar\frac{\partial}{\partial t}|\Psi\rangle = \hat{H}(t)|\Psi\rangle$$

Schrödinger's Eq.

$\rightarrow$

Ψ(n+1)=Ψ(n)+dt*Δ

Difference Eq.

$\rightarrow$

Solving it using RK4 Numerical Method

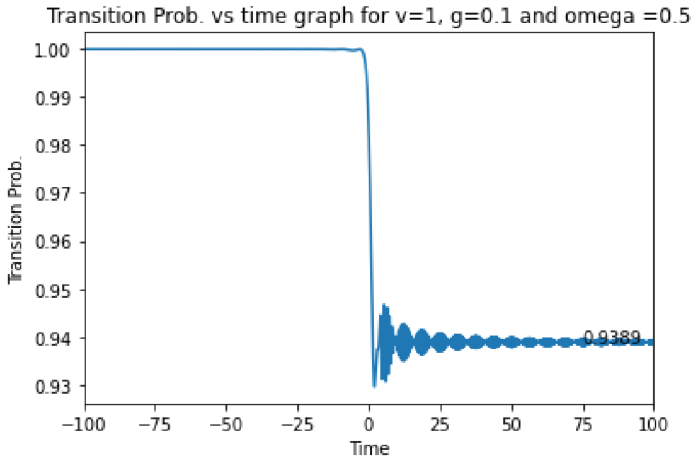
$\rightarrow$

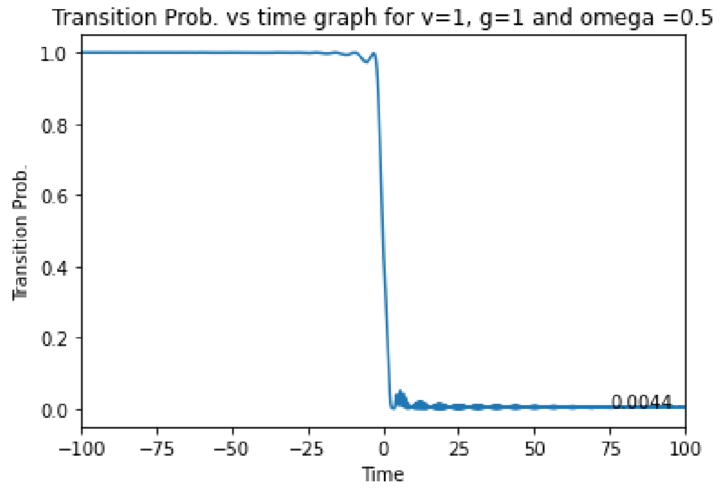
Computing and plotting the transition probabilities wrt time

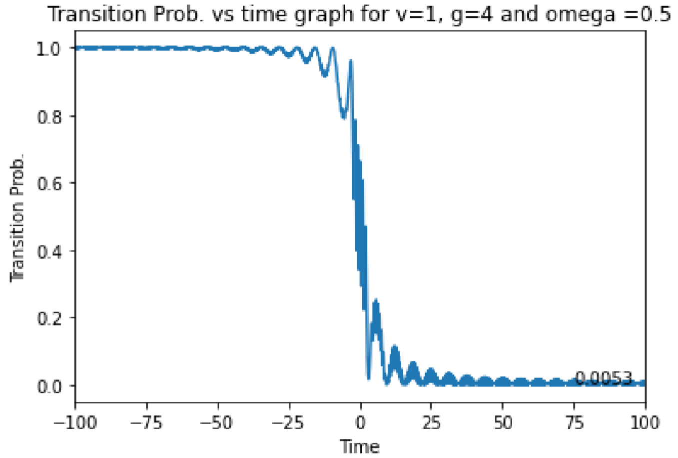
Plots for Transition Probability

g=0.1 | **g=1** | **g=4**

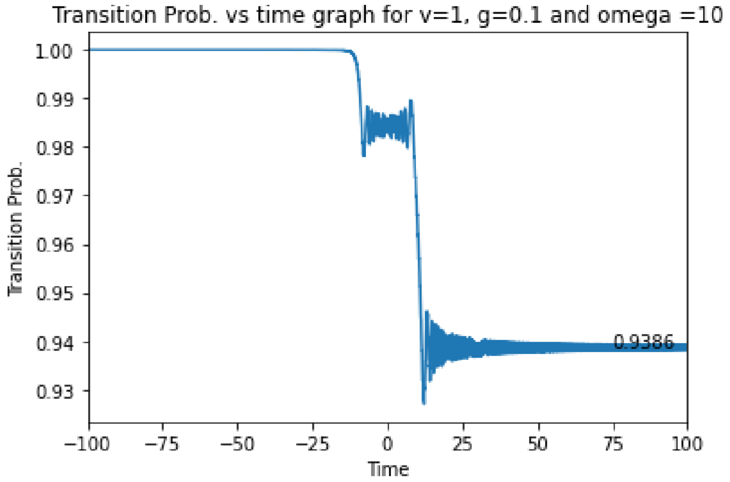
Ω=0.5

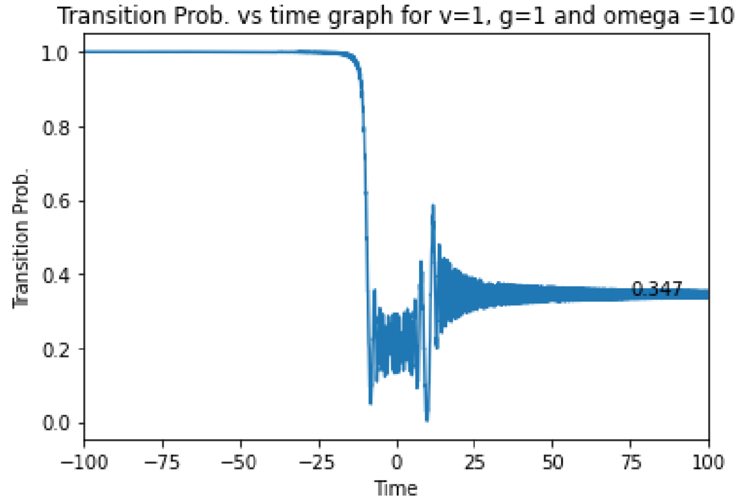


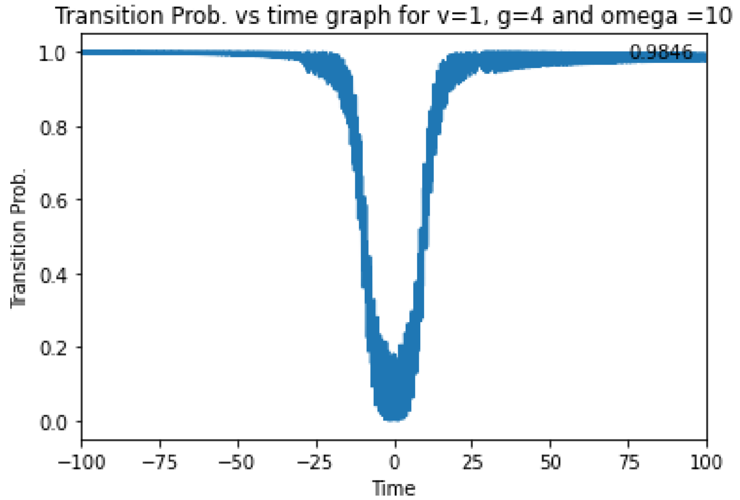




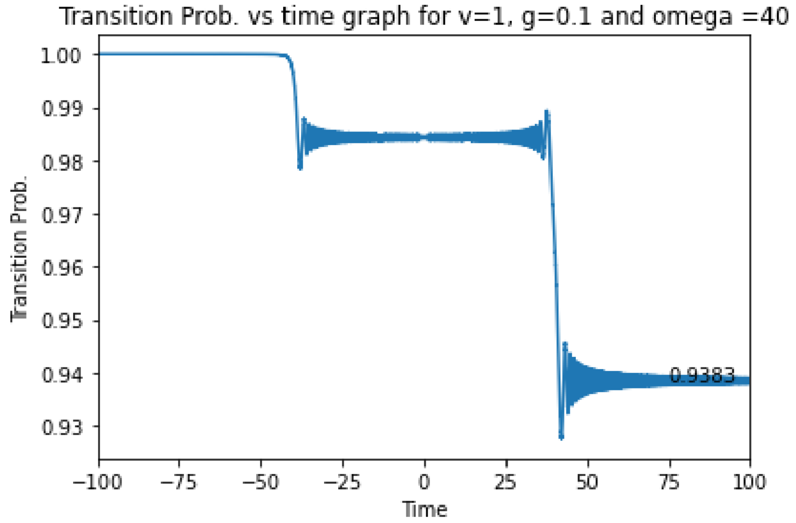
Ω=10

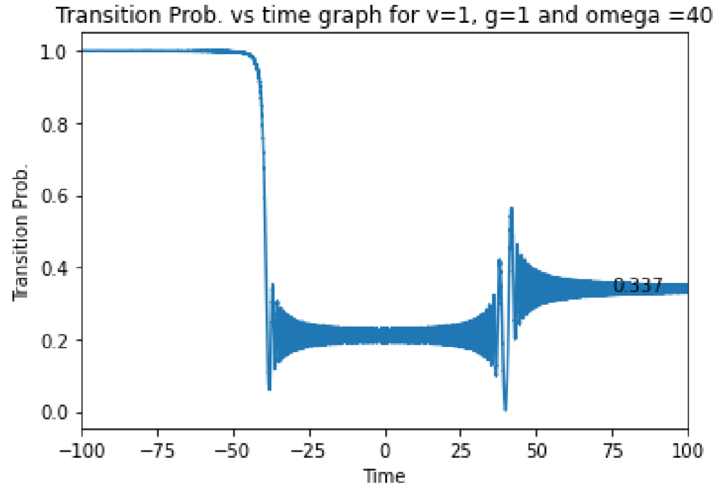


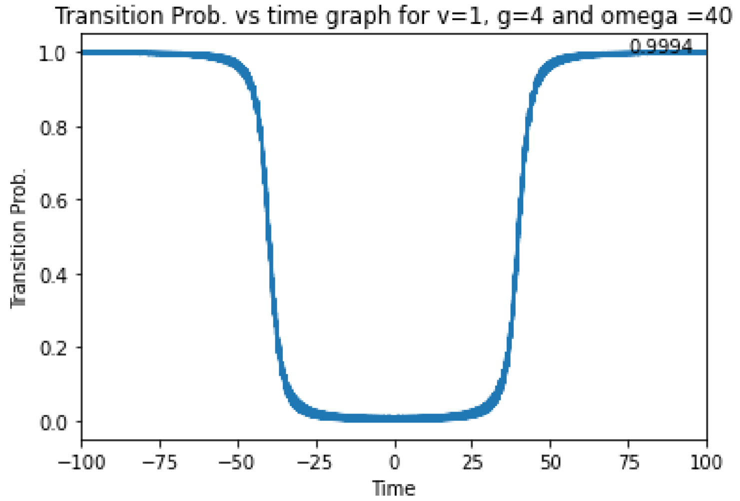




Ω=40



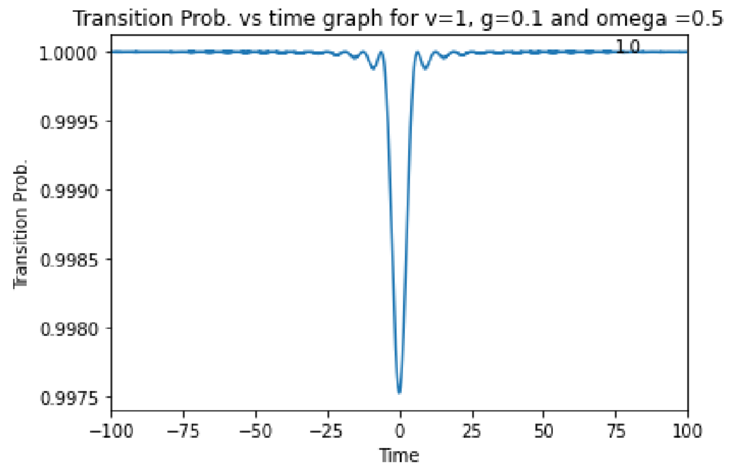


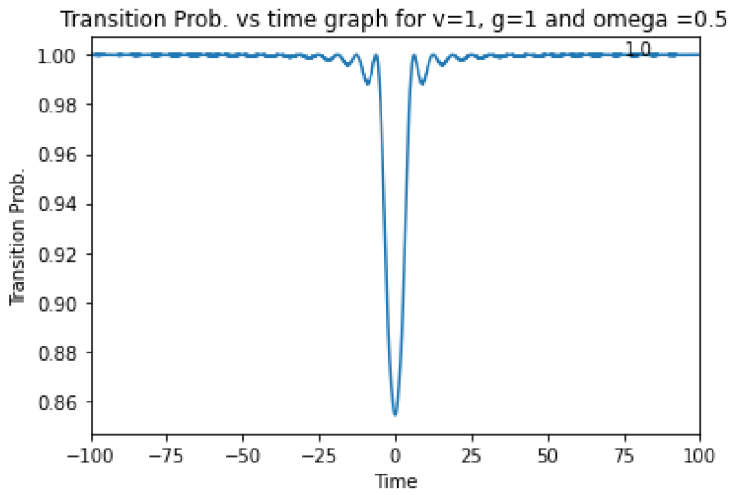


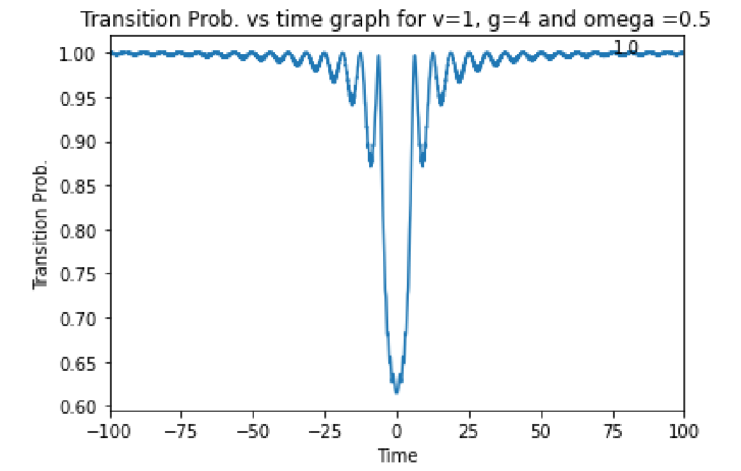
Probability Plots when Φ is an odd multiple of π/2

	g=0.1	g=1	g=4

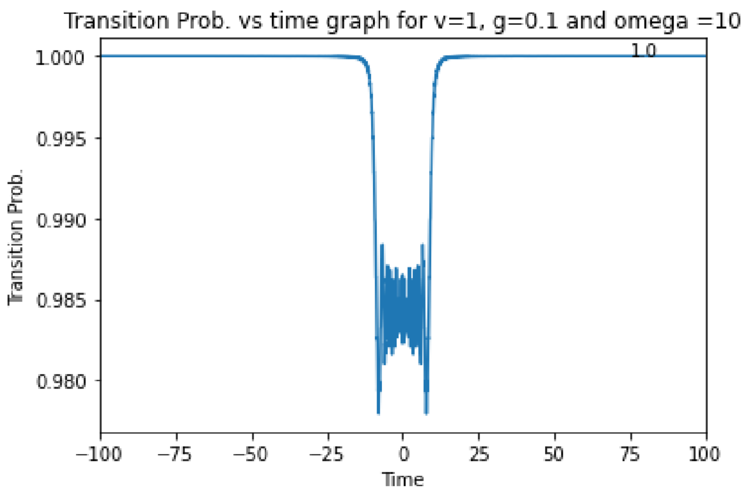
Ω=0.5

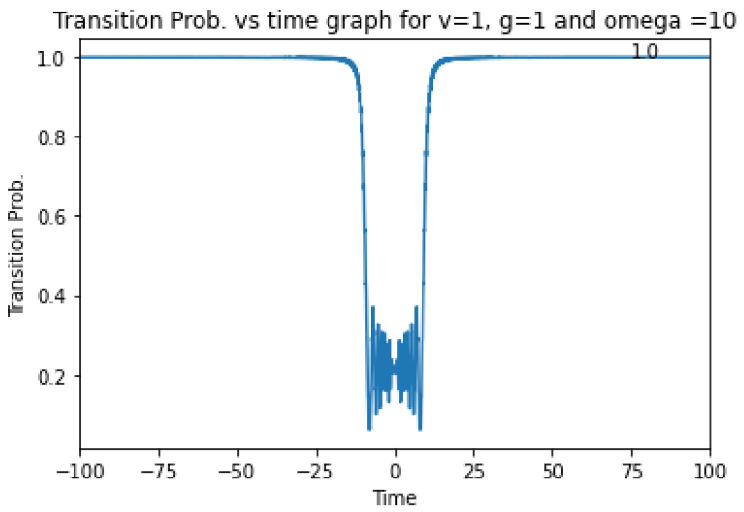


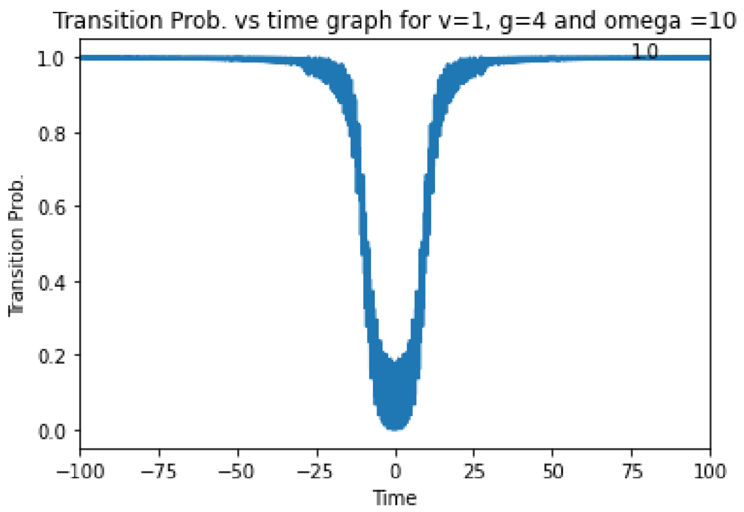




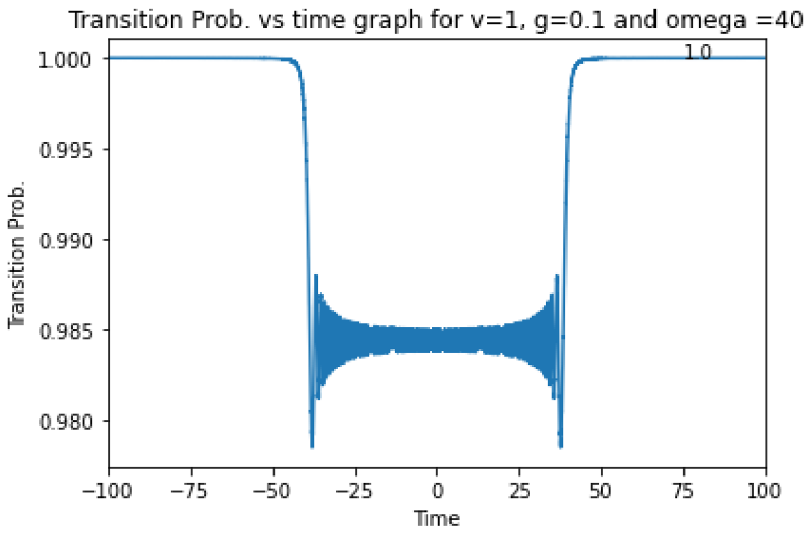
Ω=10

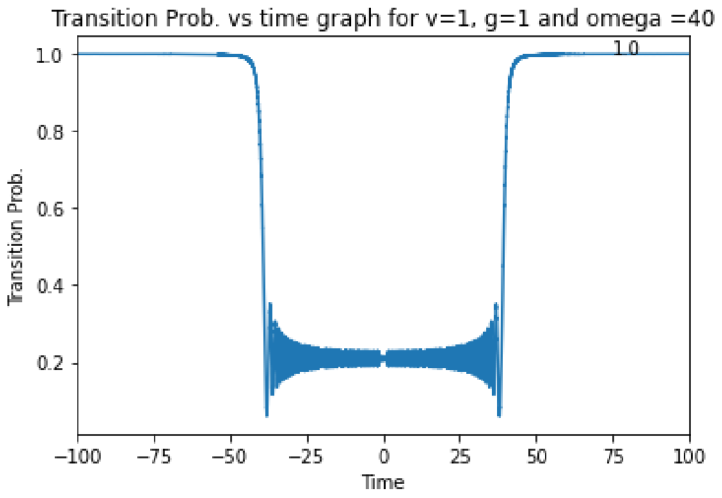


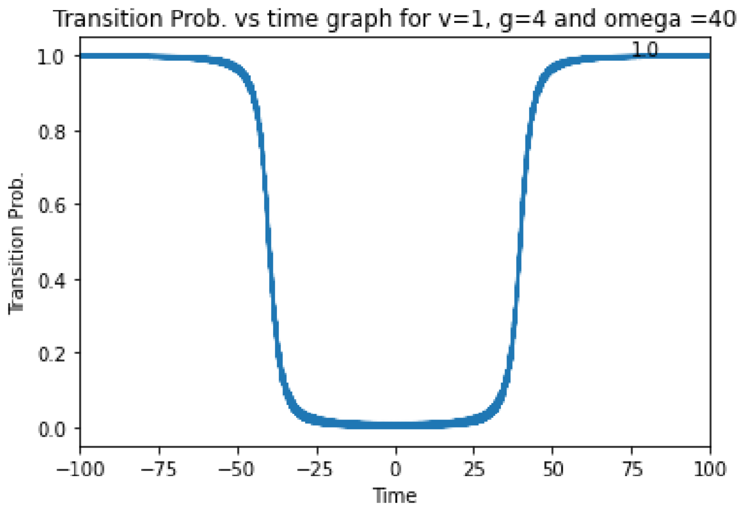




Ω=40

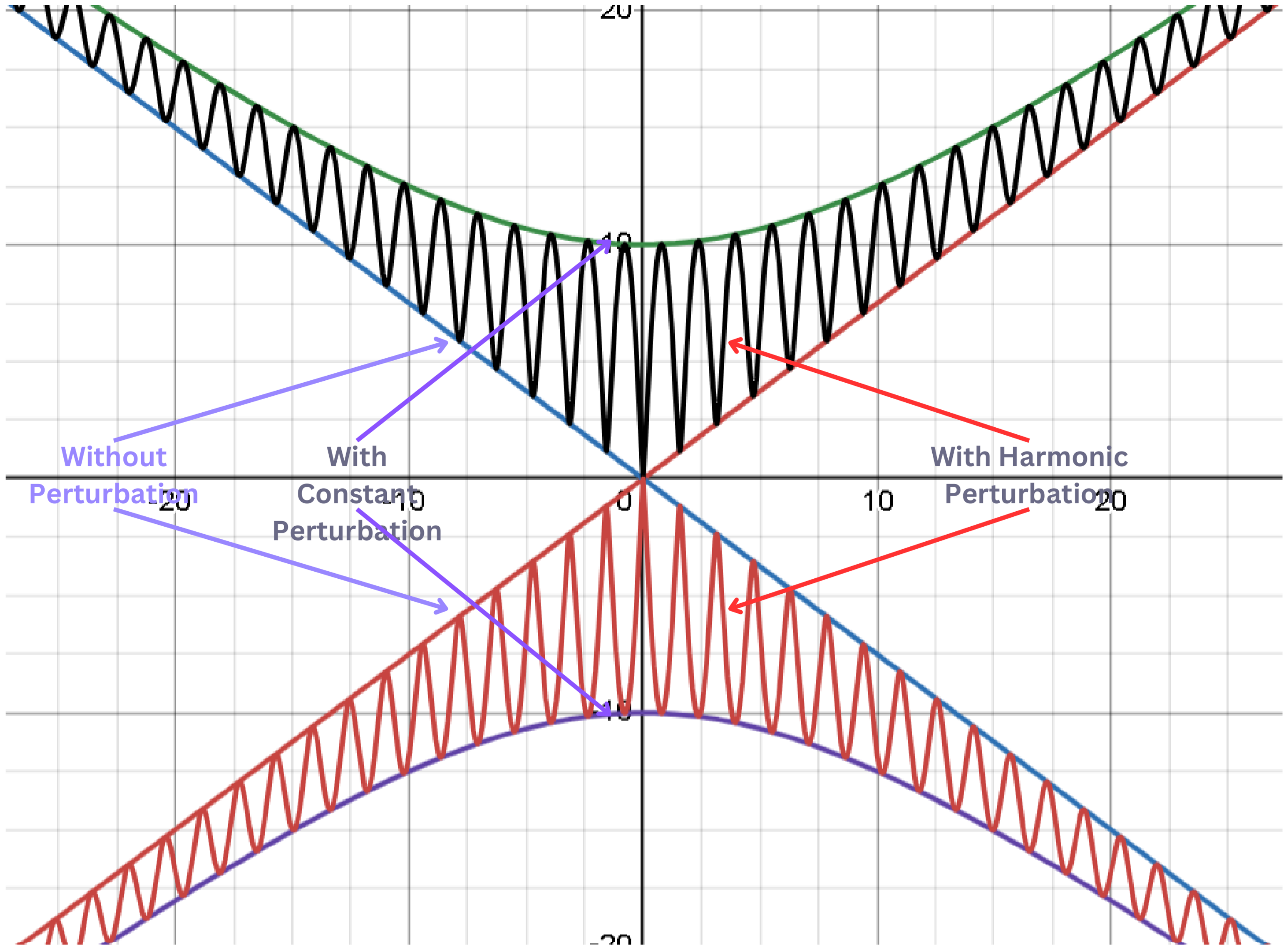






Comparison with Standard Landau-Zener

Comparison of Eigenvalues



Comparison of Trans. Prob.