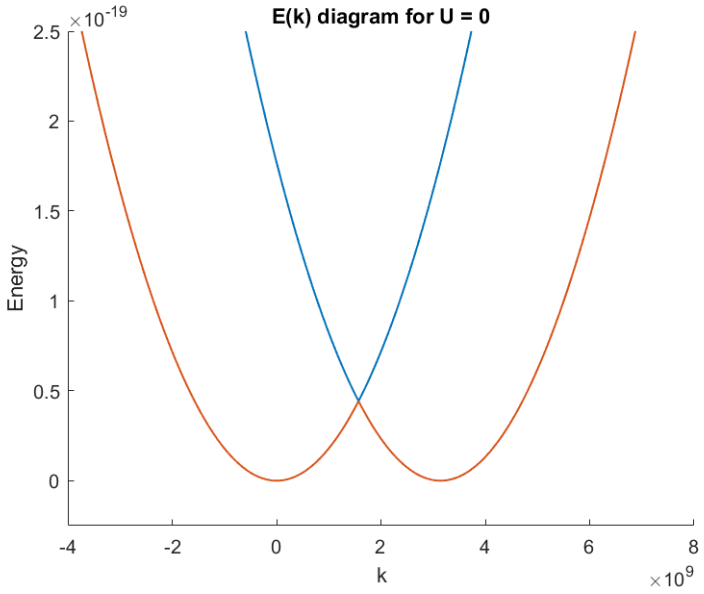
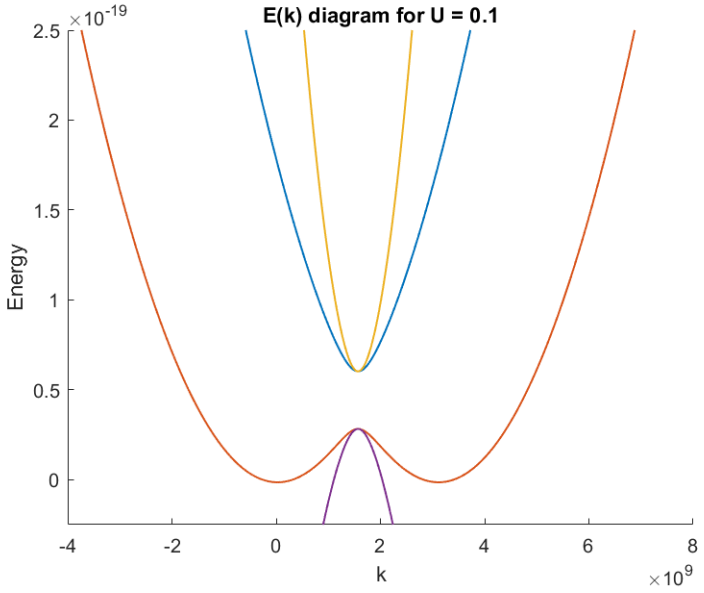
Question 4

Lattice constant ‘a’ is taken as 2e-9 m. Potential is converted to electron volts by multiplying with 1.6e-19.

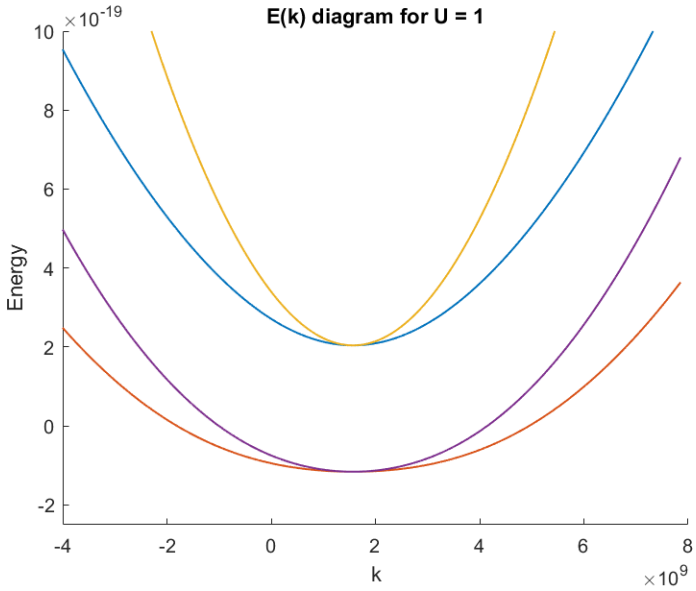
C) E(k) diagram for U = 0



D) E(k) diagram for U = 0.1 Volts



F) E(k) diagrams for U >> E_o - E_G, showing that the bands are a parabola. U is taken as 1.



The above plot shows that the band diagrams are parabolic for large values of U.

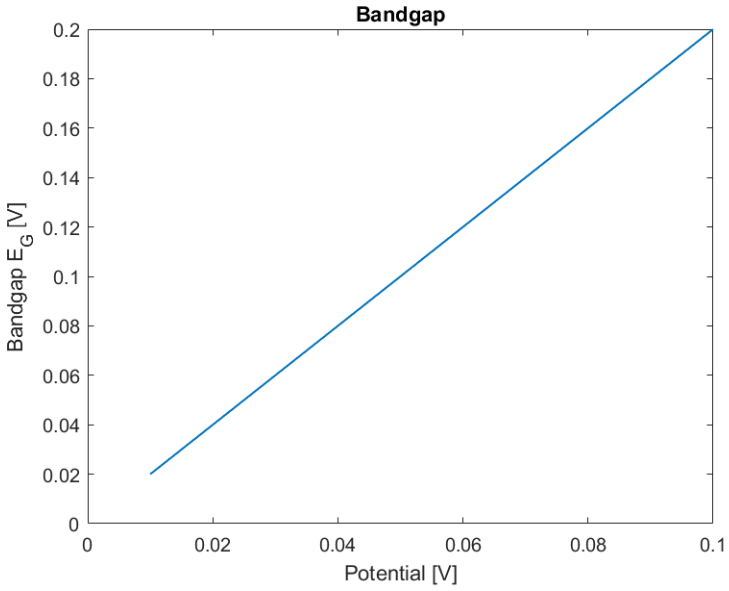
Calculation of m*:

$$m* = \frac{\hbar^2}{\frac{d^2E}{dk^2}}$$

$$\frac{d^2E}{dk^2} = \frac{\hbar^2}{m} \times \left(1 \pm \frac{2\lambda}{U}\right)$$

$$m* = \frac{m}{\left(1 \pm \frac{2\lambda}{U}\right)}$$

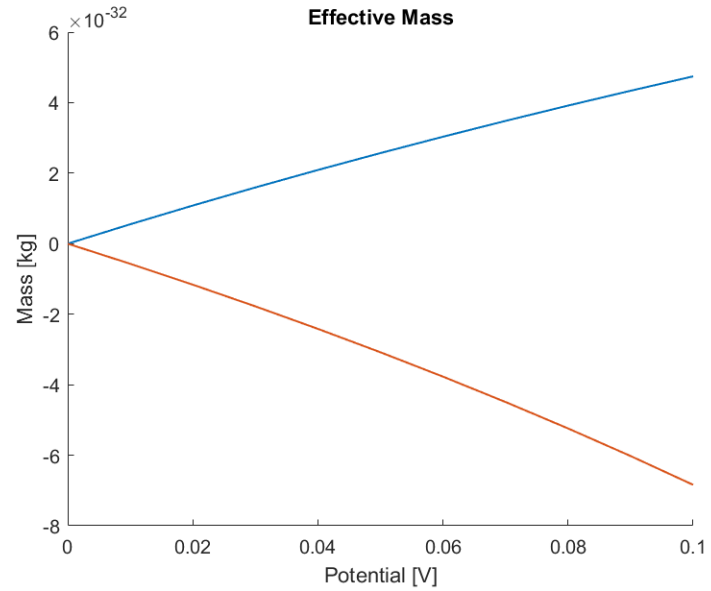
G) Bandgap Plot:



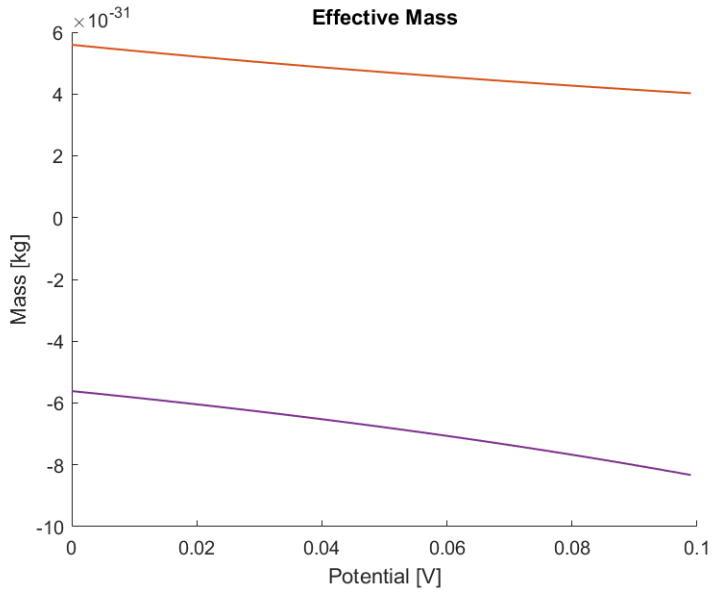
The plot is linear and slope is 2.

Effective Mass:

The effective mass is calculated as per the formula written in Q4F.



Slope of the effective mass vs potential:



Question 8 10

1. The k-space is periodic and considered as a sinusoid. Hence, when an electron moves through k-space, it will end up with same velocity periodically, and its velocity will change between those points. This is considering that no scattering occurs.
2. When scattering occurs, there should be an abrupt change to the speed and direction of motion of the electron. This will result into a sudden change in the k value of the electron.

Without Scattering:

1. For fully filled BZ:
    a. In real space, the electron gas will diffuse outwards with a velocity.
    b. In the k-space, no change would be observed. This is because since all the states are filled. When an electron leaves its state, another electron immediately fills it up.
2. For partially filled BZ:
    a. In real space, the electron gas will diffuse outwards with a varying velocity.
    b. In the k-space, at $t = 0$, some of the states will be empty since the BZ is partially filled. Hence, the BZ can be divided into two regions: filled and unfilled.
    c. At $t > 0$, as the electrons start to move, the unfilled region in the k-space will get filled with electrons, simultaneously emptying the filled region.
    d. Since no scattering is observed, there will be a net motion of the empty states through the k-space.

With Scattering:

1. For fully filled BZ:
    a. In real space, the electron gas would slowly diffuse out.
    b. In the k-space, no change would be observed.
2. For partially filled BZ,
    a. In real space, the electron gas would slowly diffuse out.
    b. In the k-space, unlike the net motion of the empty states in case of no scattering, no such net motion would be observed due to scattering events which change the velocity of the electrons.
    c. The electrons in k-space may suddenly disappear and then re-appear elsewhere in the k-space.