

Name:

Class:

WAVES  
of matter

Visual Quantum Mechanics

## ACTIVITY 11

# Moving Lonely Electrons

### *Goal*

We look at wave functions for moving electrons and describe the probabilities for its location.

We have now seen how to create a wave function for a single electron. This wave function provides information about both the location and momentum of the object. However, it cannot give us exact values for either quantity. We say that the wave function leaves us with an *uncertainty in position* and an *uncertainty in momentum* for the electron.

For the moment we will concentrate on the uncertainty in position. Use the *Quantum Motion* program to look at the wave function of an electron moving across the computer screen. We will use the same situation as in Activity 10:

- one electron,
- no interactions,
- no energy change

So, set the potential energy to zero everywhere.

The *Quantum Motion* program solves Schrödinger's Equation for the situation. It puts solutions that change with time on the screen. Thus, the wave functions represent a moving electron.

Press Play and watch what happens. Describe how the wave function changes.

Return to the starting position. Sketch the wave function below and indicate locations of high, medium and low probability of finding the electron.

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Now, play the solution, but *pause* when the wave function reaches the middle of the screen. Again, sketch it and indicate locations of high, medium, and low probability.

Continue until the wave function is near to the right side. Once again sketch it and indicate locations of high, medium, and low probability.

? Compare the three wave functions that you sketched. What changed as the electron moved?

? Other groups probably paused their wave functions at slightly different locations. Compare your conclusions to theirs. Are they similar?

You probably noticed that the locations of highest probability became small. The range of locations with medium and low probability became greater. (See Figure 11-1).

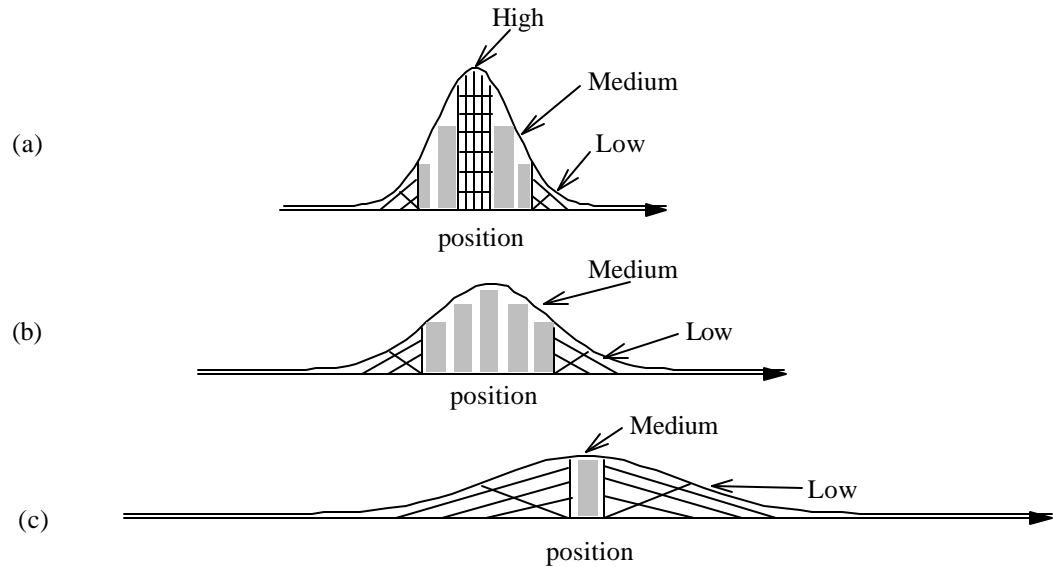


Figure 11-1: The wave function spreads out of time. Thus, the range of probability locations increases.

We can understand this result by returning to the momenta involved. We start with a wave function as in Figure 11-1(a). The electron can have many different momenta. (Remember we needed all those momenta to construct its wave function.) Of course, it also has a range of possible locations. So, we don't quite know where it is, and we don't quite know how fast it is moving — an uncertainty in position; an uncertainty in momentum. (See Figure 11-2)

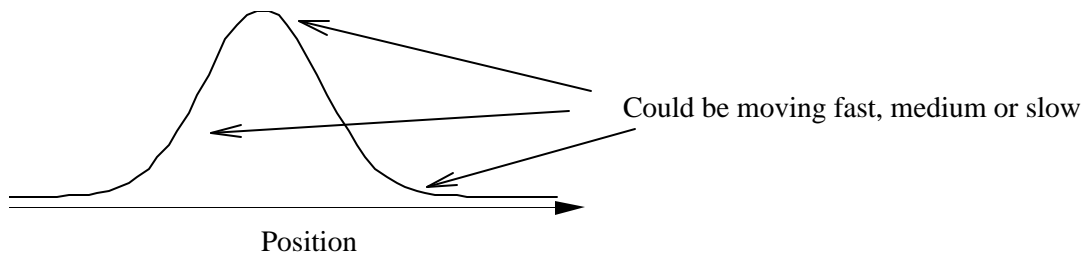


Figure 11-2: When we start, we have an uncertainty in both position and momentum.

A short time later we look to see where the electron is. We expect to still have an uncertainty in position because there was such an uncertainty when we started. In addition, the electron had an uncertainty in its momentum at the start. This uncertainty means that we do not know exactly how fast the electron is moving. The location of an object at a later time depends on both its starting point and its speed. In the case of the electron both the start and the momentum have uncertainties. As time passes the initial uncertainty in position is compounded by the uncertainty in momentum. So, as an electron moves the uncertainty in position increases.

This change in uncertainty is represented in *Quantum Motion* by a change in the wave function. As time passes, the wave function spreads out. This spreading indicates a wider range of positions is probable as the electron moves.

The rate of the uncertainty in positions depends on the uncertainty at the start. Two possible starting wave functions are shown in Figure 11-3. Wave function (a) is restricted to a very small region of space. Wave function (b) is not as restricted.

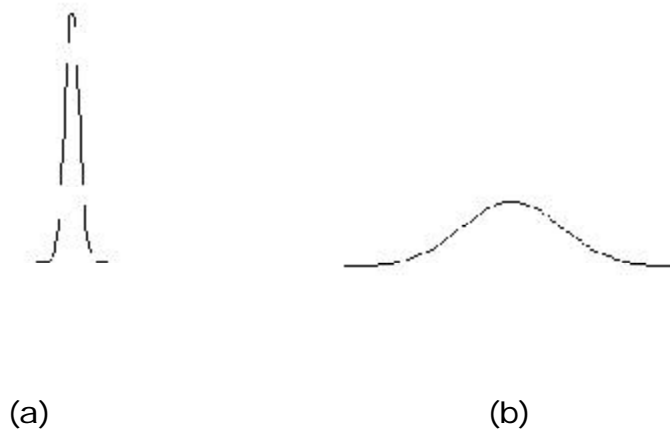


Figure 11-3: Wave functions that (a) represent an object restricted to a very small region of space and (b) not very restricted.

- ? Which one needs a larger number of momenta to create it? Refer to your experiences in Activity 10 to explain why.
  
  
- ? Use your answer above to determine which one will *change* the range of possible locations more quickly.

A very small uncertainty at the beginning results in a very rapid change in the wave function. A greater uncertainty at the start means the change in uncertainty is not so great. How well we know the position at one location determines how well we can know it later.

### Summary

The uncertainty in position and momentum of a wave function results from restricting the object to a small region of space. The wave function changes as the object moves. Because of the initial uncertainties, our knowledge of position decreases with time.