1 Visualization of Wave Functions on a Ring

Using either this *Geogebra* applet or this *Mathematica* notebook, explore the wave functions on a ring. (Note: The *Geogebra* applet may be a little easier to use and understand and is accessible if you don't have access to *Mathematica*, but it is more limited in the wave functions that you can represent. Also, the animation is pretty jumpy in some browsers, especially Firefox. Imagine that the motion is smooth.)

(a) Look at graphs of the following states

$$\Phi_1(\phi) = \frac{1}{\sqrt{2}}(|2\rangle + |-2\rangle) \tag{1}$$

$$\Phi_2(\phi) = \frac{1}{\sqrt{2}}(|2\rangle - |-2\rangle) \tag{2}$$

$$\Phi_3(\phi) = \frac{1}{\sqrt{2}}(|2\rangle + i\,|-2\rangle) \tag{3}$$

Write a short description of how these states differ from each other.

(b) Find a state for which the probability density does not depend on time. Write the state in both ket and wave function notation. These are called stationary states. Generalize your result to give a characterization of the set of all possible states that are stationary states.

(c) Find a state that is right-moving. Write the state in both ket and wave function notation. Generalize your result to give a characterization of the set of all possible states that are right-moving.

(d) Find a state that is a standing wave. Write the state in both ket and wave function notation. Generalize your result to give a characterization of the set of all possible states that are standing waves.