```
      double previousTime =
         Math.sqrt(Math.pow(y[i-1]-y[i], 2)+1)/v[i-1];
      previousTime += Math.sqrt(Math.pow(y[i+1]-y[i], 2)+1)/v[i];
      double trialTime =
         Math.sqrt(Math.pow(y[i-1]-yTrial, 2)+1)/v[i-1];
      trialTime += Math.sqrt(Math.pow(y[i+1]-yTrial, 2)+1)/v[i];
      if(trialTime<previousTime) {
         y[i] = yTrial;
      }
      steps++;
   }
}
```

Listing 7.7 Target class for Fermat.

```
package org.opensourcephysics.sip.ch07;
import org.opensourcephysics.controls.*;
import org.opensourcephysics.frames.PlotFrame;

public class FermatApp extends AbstractSimulation {
   Fermat medium = new Fermat();
   PlotFrame path = new PlotFrame("x", "y", "Light path");

   public FermatApp() {
      path.setAutoscaleX(true);
      path.setAutoscaleY(true);
      path.setConnected(true); // draw lines between points
   }

   public void initialize() {
      medium.dn = control.getDouble("Change in index of refraction");
      medium.N = control.getInt("Number of media segments");
      medium.initialize();
      path.clearData();
   }

   public void doStep() {
      medium.step();
      path.clearData();
      for(int i = 0;i<=medium.N;i++) {
         path.append(0, i, medium.y[i]);
      }
      path.setMessage(medium.steps+" steps");
   }

   public void reset() {
      control.setValue("Change in index of refraction", 0.5);
      control.setValue("Number of media segments", 2);
      path.clearData();
      enableStepsPerDisplay(true);
   }

   public static void main(String[] args) {
      SimulationControl.createApp(new FermatApp());
   }
}
```


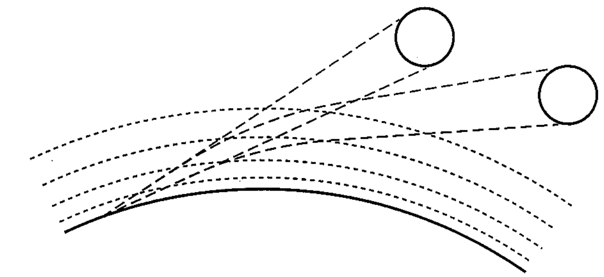

Figure 7.13 Near the horizon, the apparent (exaggerated) position of the sun is higher than the true position of the sun. Note that the light rays from the true sun are curved due to refraction.

Problem 7.37 The law of refraction

(a) Use `Fermat` and `FermatApp` to determine the angle of incidence θ_1 and the angle of refraction θ_2 between two media with different indices of refraction. The angles θ_1 and θ_2 are measured from the normal to the boundary. Set $N = 2$ and let the first medium be air ($n_1 \approx 1$) and the second medium be glass ($n_2 \approx 1.5$). Describe the path of the light after a number of trial paths are attempted. Add statements to the program to determine θ_1 and θ_2, the vertical position of the intersection of the light at the boundary between the two media, and the total time for the light to go from `(0,y[0])` to `(2,y[2])`.

(b) Modify the program so that the first medium represents glass ($n_1 \approx 1.5$) and the second medium represents water ($n_2 \approx 1.33$). Verify that your results are consistent with $n_2 \sin\theta_2 = n_1 \sin\theta_1$. ■

Problem 7.38 Inhomogeneous media

(a) The earth's atmosphere is thin at the top and dense near the earth's surface. We can model this inhomogeneous medium by dividing the atmosphere into equal width segments each of which is homogeneous. To simulate this atmosphere run your program with `N` $= 10$ and `dn` $= 0.1$ and find the path of least time. Use your results to explain why the sun is already below the horizon when we see the sun set (see Figure 7.13).

*(b) Modify your program to find the appropriate distribution $n(y)$ for a fiber optic cable, which we take to be a flat, long ribbon. In this case the ith region corresponds to a cross-sectional slab through the cable. Although a real cable is three-dimensional, we consider a two-dimensional cable for simplicity. We want the cable to have the property that if a ray of light starts from one side of the cable and ends at the other, the slope dy/dx of the path should be near zero at the edges so that light does not escape from the cable. ■

Fermat's principle is an example of an extremum principle. An extremum means that a small change ϵ in an independent variable leads to a change in a function (more precisely,