**Exercise 3: Solving a hard problem**

If you launch a projectile off the top of a cliff, with initial height h, the range R at which the projectile strikes the ground will depend on the initial speed vo, the launch angle θ, the initial height h, and the gravitational field g. The relationship between R, vo, g, and θ in this case is *not* simply the “range equation”

R=(vo)2sin(2θ)/g

The reason is that equation is derived for the case in which the launch point and impact point are at the same elevation, which is not the case here.

**ASSIGNMENT PART A**

1. Derive an equation for R as a function of vo, θ, g, and h.
2. Check your answer by letting h go to zero: the result should simplify to the same-elevation answer.

**AND NOW FOR SOME COMPUTER WORK**

The h-dependent range equation derived in part (1) above makes it easy to figure out how far something will go for a given launch angle. But what if you want to know what launch angle to use to hit a target at a known range R? It’s possible to invert the equation, but it’s quite difficult algebraically. Instead, let’s use Python.

What we have is R=f(θ), assuming that vo and h are constants. The usual way to solve things computationally is to rearrange this like so:

F(θ)≡f(θ)−R (2)

Having done that, we can plot F(θ), and graphically determine the value of θ for which F(θ)=0.

**ASSIGNMENT PART B**

Using what you’ve learned so far, write a function F(θ) that returns the value of f(θ)−R. Plot F(θ) versus θ, and using the zoom tool on the resulting graph determine the value of θ for which F(θ)=0. Report your answers to at least two decimal places. Be sure to save your work; you’ll need it for the next exercise! Use these values: R=2.5m, h=1.2 m, vo=4.8 m/s. There may be more than one correct answer.