Gravitational Force and Acceleration Activity:
"The Magic Coin Drop"

(Excerpted from *The Physics Teacher* (April 1980) and featured in *A Potpourri of Physics Teaching Ideas* (Donna Berry, Ed., American Association of Physics Teachers, 1986)

From "The Prestige" (Touchstone Pictures, 2007)…

There are three parts, or acts, in any magic trick…

Act 1 is called, "The Pledge" [introduction of something ordinary]

Act 2 is called, "The Turn" [the act of taking the ordinary something and making it do something extraordinary]

Act 3 is called, "The Prestige" [the toughest part; bringing it back]

Act 1: "The Pledge"
Grip 3 coins in one hand, held about 10 inches above your other hand as shown to the right (quarter-nickel-quarter). Predict what will happen when you drop the lower quarter and its nickel "rider" into the palm of your opposite hand while holding the upper quarter.
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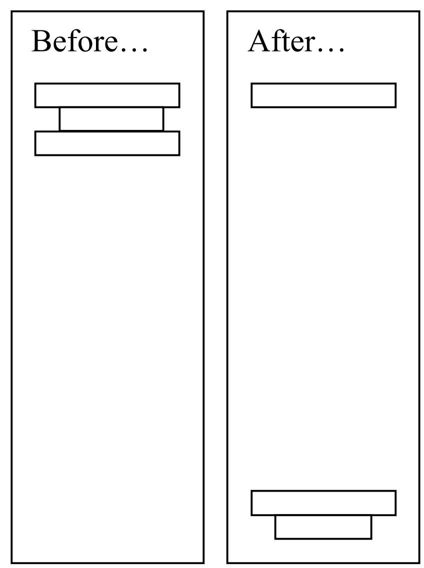

Act 2: "The Turn"
Observe the results. Repeat several times. Does the diagram accurately predict your observed results? Can you cause the coins to <u>not</u> complete a 180^{o} turn?

Act 3: "The Prestige" From what height must the lower coins be released to complete a 360^{o} turn?

The physics exposed:

From the article:
"It is nearly impossible to release both sides of the quarter at the same instant, and the side first released starts at once to turn about the opposite side. This turning motion continues as the coin falls, and the nickel falls below the quarter which is very odd to the uninformed observer…If it takes a fall of approximately 10 inches for the coins to rotate180^o, many students believe it will take 20 inches for the coins to land again with the nickel above the quarter. ***In fact, of course,*** *it is 40 inches. Once released, the coins rotate at a constant speed and so form a clock, since there is no torque, and the distance fallen will be proportional to the square of the angle of rotation.*

An alternative "spin" on the explanation…

The coins are "rotating" at a *constant* rate. They are "falling" at an *accelerated* rate, according the following free-fall equation:

$$\text{Distance} = \tfrac{1}{2} at^2 \text{ (assuming no initial vertical velocity)}$$

So if the time for a 50% rotation is, say, t_1 seconds at a distance of 10 inches, it would require twice that time ($2\ t_1$) seconds for a rotation of 100%. During $2\ t_1$ seconds of free-fall, one can calculate the proportional distance traveled (a, the acceleration of gravity, is constant, and can therefore be neglected in the proportion, as can the fraction ½). The proportion thus established indicates that *doubling* the time has the effect of multiplying the falling height by 4 (2 *squared*).

Voila!

[So there's the "prestige!" Now, there's just one more thing to do… **Try it!** Do your observations fit the stated "fact"?]

Geoscience Energy Connections:
The distance/time equation for free-fall is a consequence of the work of Newton, who described gravitational forces and motion using calculus.

Gravitational force can do physical "work" on a system if the force causes an object to accelerate (Newton's Second Law: F=ma)

Earthquakes, mudslides, lahars, waterfalls, tides, erosion and deposition, and planetary motion are all examples of geoscience connections to Newton's 2nd Law.