**Gravitational Potential Energy**

**And Conservation of Energy**

**Introduction**

The conservation of energy is one of the central conservation laws in physics. Energy may take the form of potential energy or kinetic energy. The term “potential” means that the energy has the potential of being converted into kinetic energy. In this lab we study the conversion of gravitational potential energy into kinetic energy, and develop the idea of an *equipotential surface.*

**Theory**

We usually describe the gravitational potential energy Ug of an object of mass *m* in a uniform gravitational field by Equation 1.

Ug = *m*g*H* (1)

The g is the acceleration experienced by the object in the uniform gravitational field. The distance of the object in the vertical direction from a reference point (the floor, the surface of the earth, etc.) is denoted by *H*.

If an object starts from rest and slides down a ramp of negligible friction the speed vf at the bottom of the ramp is given by

(*m*/2)vf2 = *m*g(*H*i – *H*f)

vf = (2g(*H*i – *H*f))1/2 (2)

In Equation 2 *H*f is the final height of the object and *H*i is the initial height of the object. The difference between *H*i and *H*f is the vertical distance through which the object falls. It does not matter how long the ramp is as only the vertical distance has an effect on the velocity of the object.

The lab exercise illustrates two consequences of Equation 2. The first is that the length of travel down the ramp does not affect the final velocity. The second point is that the final velocity is proportional to the square root of the height through which the object falls.

The experimental apparatus is shown in Figure 1. The horizontal piece shown is a length of aluminum channel with an inside diameter of 1”. The ramp is a length of aluminum channel with an inside diameter of 3/4”. The ramp fits snugly in the horizontal piece, and is held in place by a piece of duct tape inside the channels at point P.

The object that we use is a steel ball with a 1” diameter. The ball rolls down the ramp and is directed horizontally off the table by the horizontal channel. Since the ball ,m rolls down the ramp, our analysis is more complicated than that shown in Equation 2. The ball has **translational kinetic energy *K*tr and rotational kinetic energy *K*rot**. This means that Equation 2 becomes

*K*tr + *K*rot = Ug (3)

The translational kinetic energy is (*m*/2)v2, but the rotational kinetic energy is more complicated. For our immediate purposes the important fact is that the rotational kinetic energy is proportional to the square of the velocity, so we may write Equation 3 as

C *m* v*f2* = *m*g(*H*i – *H*f)(4)

In Equation 4 the quantity C is a constant. This may be simplified to Equation 5 as

vf = (g/C)1/2 (*H*i – *H*f)1/2 (5)

If we look at Figure 1 we see that the time *t* the ball is in the air once it leaves the horizontal channel is given by Equation 6.

*t* = (2D/g)1/2 (6)

The distance *S* that the ball travels in the horizontal direction is given by

*S* = vf *t*

*S* = (g/C)1/2 (*H*i – *H*f)1/2 (2D/g)1/2

*S*2 = (2D/C)(*H*i – *H*f) (7)

**Part One: Gravitational Equipotentials**

Set up the ramp by applying duct tape to the inside of the channels at point P, about 15 cm from the end of the horizontal channel.

Apply small pieces of painters tape to the horizontal channel at 40 cm, 55 cm, 70 cm, and 85 cm from point P.

Use duct tape to fasten the horizontal channel to the table. Two pieces should suffice. The horizontal channel should overhang the table by 10 cm or so.

Use painters tape to fasten paper to the floor from a point directly below the end of the horizontal channel to a distance of 3.4 meter or so from the end of the channel.

Use a plumb bob to mark a point directly below the end of the horizontal channel.

Measure the vertical distance D.

Put a single wooden block under the ramp at the 40 cm mark. Place the ball so that its forward edge is even with the edge of the block. Release the block and see the spot where it lands on the paper. Center a piece of carbon paper on that spot and lay (do not tape) another piece of paper on top of the carbon paper. Release the ball and note the mark on the paper taped to the floor.

Move the wooden block to the 55 cm mark and release the ball as before. Note the mark made by the ball’s impact. Move the block to the 70 cm mark and release the ball, marking the impact on the paper. Move the block to the 85 cm mark and release the ball, marking the impact on the paper.

All of the impacts should be very close to each other, indicating that the velocity that the ball had as it left the horizontal channel was the same in each case.

Repeat this procedure for a pair of stacked blocks at each of the intervals of 40, 55, 70, and 85 cm.

**Part Two: Converting Gravitational Potential Energy into Kinetic Energy**

Place three blocks at the 70 cm mark and release the ball, noting the mark on the paper.

Place four blocks at the 70 cm mark and release the ball, noting the mark on the paper.

Place five blocks at the 70 cm mark and release the ball, noting the mark on the paper.

Remove the paper from the floor, and measure the distances *S* that you obtained for ramp heights of 1, 2, 3, 4, and 5 blocks.

Graph the appropriate function of the distances *S* and the ramp height in blocks so that you obtain a straight line. Determine the value of the constant C from the slope of the straight line.