Ballistic Pendulum

PreLab submission with a pass grade is required to begin the lab.
Must be submitted no later than right before the start of the lab.

Name: Aryan Malhotra
Section: H4
Date: 10/23/2024

Purpose

To understand the conservation of energy and momentum.

Readings

You can explore these concepts using Wikipedia or yous favorite mechanics textbook,
Conservation of Energy, Conservation of momentum, Elastic collision, Inelastic collision,
Kinematics, kinematics equations,

Use these simulations to get familiar with the lab,
Ballistic Pendulum
Projectile Motion

And review the Error Propagation chapter from Taylor's book.

Theory and concepts in short

In the absence of external forces momentum of a system is conserved. In the two body collision the total momentum of the system before and after the collision are given by

$$\mathbf{p}_{\mathrm{i}} = m_1 \mathbf{v}_{1\mathrm{i}} + m_2 \mathbf{v}_{2\mathrm{i}}$$

$$\mathbf{p}_{\mathrm{f}} = m_1 \mathbf{v}_{1\mathrm{f}} + m_2 \mathbf{v}_{2\mathrm{f}}$$

where the subscripts "i" and "f" stand for "initial" and "final."
Mechanical energy is the sum of kinetic and potential energies. The law of conservation of energy states that the total energy of a system is always conserved. However, unlike momentum and total energy, kinetic energy is not usually conserved. A collision in which kinetic energy is conserved is an elastic collision. In an inelastic collision some of the kinetic energy is converted into non-mechanical energy (often heat). Total energy is still conserved, but mechanical energy is not. Inelastic collisions in which two bodies stick together (sometimes called perfectly inelastic collisions) have a maximum loss of kinetic energy.

An example for error propagation

You have measured various quantities y and h with uncertainties Δy and Δh. Now you want to use these measurement to calculate a quantity x which is a function of your measured quantities,

x = f(y,h).
The uncertainty in x is then given by,

$$\Delta x = \sqrt{\left(\frac{\partial f}{\partial y}\,\Delta y\right)^2 + \left(\frac{\partial f}{\partial h}\,\Delta h\right)^2},$$

where $\frac{\partial f}{\partial y}$ is the partial derivative of f with respect to y. All that is meant by the term partial derivative with respect to y is that ignore that h is a variable and just take the regular derivative $\frac{df}{dy}$.

Dialog:

Problem 1. Ballistic Pendulum

Consider a steel ball of mass m that is fired from a spring-loaded gun into a catcher-swing of mass M. The ball has an initial velocity of v. The catcher is initially at rest and is free to swing like a pendulum. After capturing the ball, the catcher+ball have a velocity V. *At the moment the ball is captured* there is no net external force acting on the catcher+ball system, thus its linear momentum is conserved. Note that the kinetic energy is not conserved in this collision because of the dissipating force of friction which locks the ball into catcher.

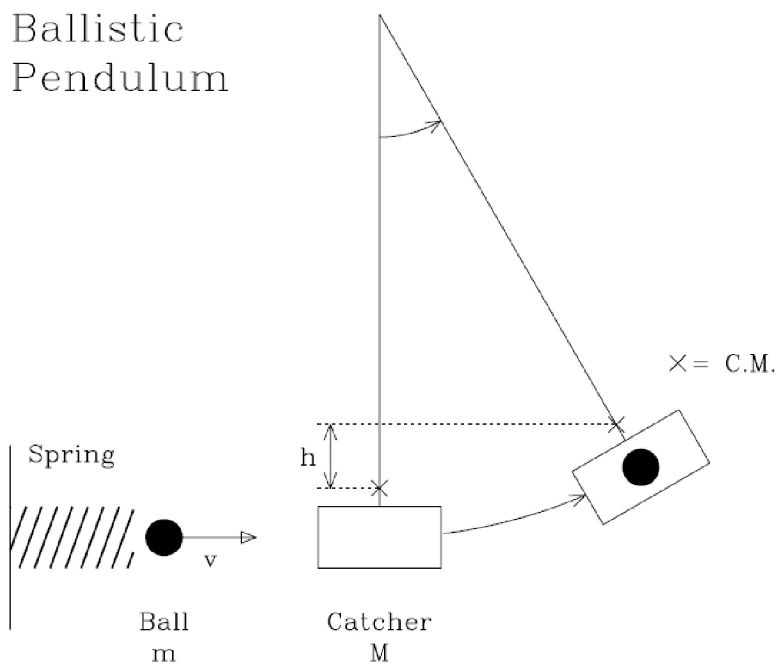

Figure 1: Ballistic Pendulum

After the ball is caught in the catcher and the swing-arm starts to move, momentum is no longer conserved because there is a net external force (the force of the swing-arm and gravity is no longer parallel). However, once the swing-catcher starts in motion, conservation of mechanical (kinetic+potential) energy applies because the force of the swing-arm is always perpendicular to the motion of the catcher. As shown in Figure 1, the catcher with the ball continues to swing upward until it stops with its center of mass at a vertical distance, h, above the starting level.

- Use the conservation of momentum and energy to calculate the initial velocity of the steel ball, v, from the quantities below.

In[1219]:=

```
m = 0.050; (*Kg*)
M = 0.200; (*Kg*)
h = 0.10; (*m*)
KE2 = N[(m + M) * 9.81 * h]
v2 = N[Sqrt[2 KE2 / (m + M)]]
(*mv1=(m+M)v2 implying v1 = v2(m+M)/m*)
v1 = N[v2 * (m + M) / m]
```

Out[1222]=

```
0.24525
```

Out[1223]=

```
1.40071
```

Out[1224]=

```
7.00357
```

- Using the error propagation rules, calculate the Error σ_v assuming that uncertainty of the height h measurement, δh/h, is 10%.

being in a square root, the error in v would be 1/2 * error(h) = 5%
hence, v2 = 1.4 ± 0.07 m/s
v1 would have 2 sigfigs and error would be 5% again
v1 = 7.0 ± 0.35 m/s

Problem 2. Projectile.

In this part the spring-loaded gun is used to fire the ball horizontally from an initial elevation y with initial velocity v. The ball hits the floor at a distance x as shown in Figure 2.

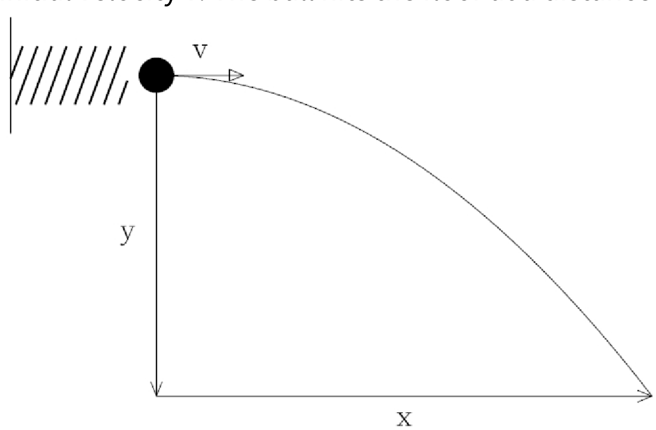

Figure 2: Range of Projectile

- Using the quantities below calculate the horizontal distance x, and record it in the table below.

```
m = 0.050; (*Kg*)
v = 7.0; (*m/s*)
y = 1.00; (*m*)
(*y=gt^2/2 implying t = Sqrt(2gh)*)
t = Sqrt[2*9.81*y]
R = N[v*t]
```

Out[1228]=

```
4.42945
```

Out[1229]=

```
31.0062
```

R = 31.0062 m

- Calculate the Error σ_x assuming that uncertainty of the velocity v, δv/v, is 5% and uncertainty of the height y, δy/y, is 1%.

Again, t would have half the error as y which is 0.5%
Hence, R would have 2 sigfigs and 5.5% error i.e. 31 ± 1.7 m

```
31*5.5/100
```

Out[1231]=

```
1.705
```

Results Table

- Record your results with errors in the table below. Use correct number of significant digits.

In[1232]:=

```
Grid[{{Text["Table P1. Ballistic Pendulum"], SpanFromLeft},
  {"m, kg", "M, kg", "h, m", "v, m/s"}, {m, M, PlusMinus[h, 0.1 h], PlusMinus[7.0, 0.35]},
  {Text["Table P2. Projectile Range"], SpanFromLeft}, {"m, kg", "v m/s", "y, m", "x, m"},
  {m, PlusMinus[v, 0.05 v], PlusMinus[y, 0.01 y], PlusMinus[31, 1.7]}}, Frame → All]
```

Out[1232]=

Table P1. Ballistic Pendulum			
m, kg	M, kg	h, m	v, m/s
0.05	0.2	0.1 ± 0.01	7. ± 0.35
Table P2. Projectile Range			
m, kg	v m/s	y, m	x, m
0.05	7. ± 0.35	1. ± 0.01	31 ± 1.7

Rutgers 275 Classical Physics Lab
“Ballistic Pendulum”
Contributed by Maryam Taherinejad and Girsh Blumberg ©2014