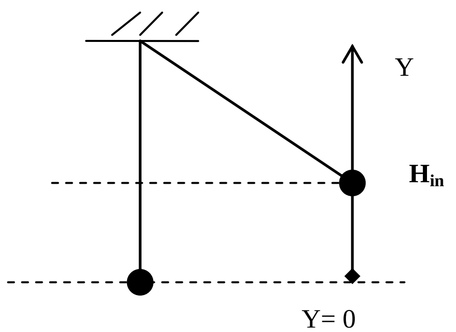
Lab on Energy of a Pendulum

Objective: To verify the principle of energy conservation in case of a mass hanging at the end of a string during its oscillations.

Theory

There are two forces acting on the mass in oscillation; the **weight** and the **tension**. The **weight** is an **internal** force of the **system mass – earth**, tension is an external force. The work by tension is zero because, during oscillations, the tension is perpendicular to the displacement. So, the net external work $\mathbf{W_{ext} = 0}$ and the formulae $\mathbf{W_{ext} = E_{fin} - E_{in}}$ shows that the total mechanical energy ME of the system is conserved: $\mathbf{E_{fin} = E_{in}}$. When the mass is at the initial location (higher point) the whole energy of the mass(and system) is potential $\mathbf{E_{in} = U_{in} = mgH_{high}}$. If we **place the origin of Oy axis at the lowest point**, and take $\mathbf{U_{fin}} = \mathbf{U}_{low}$ then $\mathbf{U_{fin} = mgH_{low}} = 0$.
So, *at the lowest point* the whole energy is kinetic and $\mathbf{E_{fin} = K_{fin} = mv^2 / 2}$

In this lab, essentially, you have to verify if $\mathbf{E_{fin} = E_{in}}$ that is $\mathbf{m*g*H_{high} = m*v^2_{low} / 2}$ (1)



Equipment:

- Photogate. Please be careful with the photogates. They are expensive and fragile. The teacher will show you the photogate. You are going to use it as a sensitive timer. There is a beam of invisible light going from one prong to the other, roughly like the beams used in some kinds of burglar alarms. When an object goes between the prongs and blocks the beam, the photogate timer measures for **how long** (**Δt**) the beam was blocked.
- Metal stand, clamp, string, meter stick; 100-gram (or 50g) iron mass.

Procedure :

1. Measure the mass and diameter of your 100-gram "bob". Record them on top of table #1.
2. Look at the bob and visually estimate what level is its *Center of Gravity*
3. Measure the height H_{Bottom} *from* the ***table to the Center of Gravity*** of the bob when hanging straight down at rest and record it on the top of table #1.
4. Please be sure to use the (*new)* wooden blocks so that the pendulum cannot accidentally hit the photogate. Also, be sure the computer screens are out of the way of oscillating mass.
   Bring the photogate down as low as possible. Set up the pendulum on the table so that, when hanging straight down at rest, the bob is inside the photogate, blocking the beam. String **length should be about 80cm to 100 cm**.
5. Now do ***4 -5 runs***. For each run:

- Calculate **H_{top}**, from table to CG of bob just before you drop it.
- Release the bob from rest at **H_{top}** and let it swing through the photogate. The team partner must catch it before it swings back.
- Record the photogate reading "**t**".
- Repeat three times the run with the same **H_{top}** .You will calculate later **t_{best}, Δt**.

Insert all the measured data into table_1.

Table_1 m_{bob}[g] = D_{bob} [cm]= H_{bottom}[cm] =

Run #	H_{in} (cm)	H_{top} (cm)	t_1(sec)	t_2(sec)	t_3(sec)	T_{best}(sec)	Δt(sec)
1	2	H_{bottom}+2=					
2	4	H_{bottom}+4=					
3	6	H_{bottom}+6=					
4	10	H_{bottom}+10=					
5	14	H_{bottom}+14=					

Analysis of the data:

1. For each height, calculate:
   - **t_{best}** based on the three trials for this run and **Δt**.
   - the best estimation for U as $\boldsymbol{U = mgH_{in}}$ and $\Delta \boldsymbol{U = mg\Delta Hi_n}$. Use **$g = 9.8 m/s^2$**, not 10.
   - the best estimation for speed of bob $\boldsymbol{\upsilon_b}$ and $\boldsymbol{\Delta\upsilon}$ at the bottom based on $\boldsymbol{\upsilon = D / t}$.
   - the best estimation for K using the formula $\mathbf{K_B = m\upsilon_b^2/2}$ and $\mathbf{\Delta K = m\upsilon_{Av}\Delta\upsilon}$

   Collect your calculated results in table_2.

   Table#2

Run #	H_{in} (cm)	ΔH_{in}(cm)	U(..)	ΔU(…)	υ (...)	Δυ (...)	K(…)	ΔK(...)
1	2							
2	4							
3	6							
4	10							
5	14							

- To get an idea about the magnitude of system energy in SI units calculate $E_{H=14cm}$ (in joules).
- As energy values are small numbers in SI units you should express them in scientific notation. You may not use SI units for energy but don't forget to note the units for K and U in table 2.

2. Plot the graph of U versus K, with one point for each run. Find the best estimation for the slope of graph and its uncertainty. This is your "experimental" value of slope. What value do you expect for the slope?
3. Calculate the **% difference** between the measured and expected theoretical value for the slope. What are you estimating this way; the **precision** or the **accuracy**?
4. Remember to include one sample calculation for each type of calc.