Swinging Pendulum Activity –
Swinging Pendulum Worksheet – Answers

Data

1. Measure the mass of your weight.
2. Measure the distance from the ceiling to your weight.
3. Place two pieces of tape on the wall/other surface that are 50 cm apart with your weight in the middle.
4. Measure the height from the floor to the bottom of the weight when it is at equilibrium and again when the bottom is at one of the pieces of tape.
5. Record the time it takes for the weight to swing to the piece of tape on the other side (t_1).
6. Record the time it takes for the weight to swing to the other side and back again (t_2).
7. Perform three trials of this experiment.

Mass of Weight (kg)	Ceiling to Weight (m)	Floor to Weight At Equilibrium (m)	Floor to Weight At Tape (m)	t_1 (s)	t_2 (s)
0.1	2.64	0.13	0.135	1.47	3.08
0.1	2.64	0.13	0.135	1.44	3.05
0.1	2.64	0.13	0.135	1.55	3.12

8. Perform the same procedures as before, except adjust the pieces of tape to be 80 cm apart.

Mass of Weight (kg)	Ceiling to Weight (m)	Floor to Weight At Equilibrium (m)	Floor to Weight At Tape (m)	t1 (s)	t2 (s)
0.1	2.64	0.13	0.145	1.39	2.94
0.1	2.64	0.13	0.145	1.54	3.12
0.1	2.64	0.13	0.145	1.43	3.05

Calculations and Results

1. Subtract t_2 from t_1 and calculate the average value for both set of trials.

Tape Separation: 50 cm

$t_2 - t_1$ (s)
1.61
1.61
1.57
Avg: 1.597

Tape Separation: 80 cm

$t_2 - t_1$ (s)
1.55
1.58
1.62
Avg: 1.583

2. Calculate the Potential Energy (PE) of the weight at the initial piece of tape for the two different tape separation values.

First Set
PE = m*g*h where m = mass, g = gravity, h = height
PE = 0.1 kg * 9.81 m/s^2 * 0.135 m
PE = 0.1324 Joules

Second Set
PE = 0.1 kg * 9.81 m/s^2 * 0.145 m
PE = 0.1422 Joules

3. Calculate the Kinetic Energy (KE) and theoretical velocity of the weight at the bottom of its swing for the two tape separation values.

Total Energy = Kinetic Energy (KE) + Potential Energy (PE) = Initial PE
At Equilibrium: First Set
PE = 0.1 kg * 9.81 m/s^2 * 0.13 m
PE = 0.1275
Initial PE = KE + PE
0.1324 Joules = KE + 0.1275 Joules
KE = 0.0049

At Equilibrium: Second Set
Initial PE = KE + PE
0.1422 Joules = KE + 0.1275 Joules
KE = 0.0147 Joules

4. Calculate the measured velocity of the weight and compare it with the theoretical velocity by using percent error.

First Set

Theoretical Velocity – Use the Kinetic Energy value to find theoretical velocity
KE = ½ * m * v2
0.0049 Joules = ½ * 0.1 kg * v2
v = 0.3130 m/s

Measured Velocity – Use the Measured differences in times and the distance traveled by the weight
v = distance / Time
v = 0.50 m / 1.597
v = 0.3131 m/s

Percent Error = ($v_{measured}$ – $v_{theoretical}$) / $v_{theoretical}$ * 100%
Percent Error = 0.032 %

Second Set – repeat calculations from first set with the second set values

Tape Separation: 50 cm

Potential Energy (Joules)	Kinetic Energy (Joules)	Theoretical Velocity (m/s)	Measured Velocity (m/s)	Percent Error
0.1324	0.0049	0.3130	0.3131	0.032 %

Tape Separation: 80 cm

Potential Energy (Joules)	Kinetic Energy (Joules)	Theoretical Velocity (m/s)	Measured Velocity (m/s)	Percent Error
0.1422	0.0147	0.5422	.5053	6.82 %

5. Calculate the Theoretical period of the pendulum. Why do you only have to perform this calculation once and not for both of sets of trials.

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

Where T = period, l = length of pendulum, g = gravity

$T = 2\Pi * (2.64 \text{ m} / 9.81 \text{ m/s}^2)^{½}$
T = 3.259 s

This calculation only has to be performed once because the period of the pendulum is not dependent on how high up the object at the end of the pendulum begins its swing. The higher up it is, the faster it travels to the other side; the lower it is, the slower it travels. The period is only dependent on the length of the pendulum.

6. What was the measured period for each set of trials and what was the percent error for each case?

First Set
Measured Period = Avg. t_2 value
Measured Period = (3.08 s + 3.05 s + 3.12 s) / 3
Measured Period = 3.083 s

Percent Error = (3.259 – 3.083) / 3.259 * 100 %
Percent Error = 5.39 %

Second Set – repeat calculations with second set values

Theoretical Period (s)	Measured Period – 1st set (s)	Measured Period – 2nd set (s)	Percent Error – 1st set	Percent Error – 2nd set
3.259	3.083	3.037	5.39 %	6.81 %

Further Learning

7. Account for the percent error between your measured periods and your theoretical periods.

In this experiment, we did not consider wind resistance or the resistance on the swing from the tape. This resistance causes the swings to be shorter than they would be with no resistance. However, the swings will also be slower because of this resistance. Therefore, the error is smaller than would be expected from the resistances. Taking this fact into consideration, the error is also on account of

inaccurate measurements made throughout the experiment as a result of not having state-of-the-art equipment.

8. Calculate how long you would have to make a pendulum so that it would have a period of one second.

   $T = 2\Pi * (L / g)^{½}$
   $1 \text{ s} = 2\Pi * (L / 9.81 \text{ m/s}^2)^{½}$
   $L = 0.2485 \text{ m}$

9. Based on your calculations and results, would it be more efficient to have your pendulum with a period of one second swing from a higher height or a lower height? Explain.

   It would be more efficient to have the pendulum swing from a lower height. In the experiment, there was a greater error in the period of the pendulum when it started from a higher height. Therefore, starting it at a lower height would require less external energy to keep the pendulum swinging consistently at a period of 1 second.

10. You are an engineer working for an amusement park. They have asked you to develop one of the fastest roller coasters in the U.S., but they also want it to be cost efficient. Therefore, they do not want to have to use a lot of energy to break the roller coaster. How would you develop this ride so that it is still easily accessible to the amusement park guests?

    The two components to consider while building this roller coaster are the potential and kinetic energies of the roller coaster, and the weight of the roller coaster. The speed at which the roller coaster travels is not affected by the weight of the roller coaster if it gains all of its speed through a transfer of potential energy to kinetic. Therefore, a lighter roller coaster can go just as fast as a heavier one but require less energy to brake. In order to make the roller coaster travel at a top speed, it would be best to use a combination of potential energy transferred to kinetic and a launching system. The problem with this comes at the end of the ride because if the end is at the same place as the beginning, it will be traveling very fast and require a lot of energy to slow down. Therefore, we can have the end of the ride be at a higher point than the beginning so that more kinetic energy is transferred to potential. Then, after the people get off and there is significantly less weight, a braking system is used to bring the roller coaster back to the beginning.