**Introduction** This lab deals with total energy of a system.

**Purpose**

To investigate and distinguish energy in terms of potential energy (PE) and kinetic energy (KE).

**Background Information**

Potential energy (PE) represents the potential to “fall”, the potential work in the downward direction. Mathematically, PE = mgh, where m is the mass of an object, g is gravity, and h is the height the object may fall.

Kinetic energy (KE) is the work done on or by an object in motion based on unbalanced forces acting on the object. Mathematically, KE = ½ mV2, where m is the mass of the object and V is the final velocity of the object.

The total energy in a system is the sum of the PE and KE. Mathematically, Etotal = PE + KE. At times PE is Maximum, so KE = 0. At other times KE is maximum, so PE = 0. Therefore, max PE = max KE. Most of the time both PE and KE are present, so Etotal = PE + KE.

**Hypothesis**

If the maximum PE and maximum KE of an object can be calculated, then, maximum PE = maximum KE.

**Materials**

200 g mass 2 m length of string Timer

Tennis Ball Mass balance Meter stick

5 m length of string

\* If possible, perform the procedures using your own data. Otherwise, use the data provided.

**Pendulum Procedures & Calculations and Data**

1. *Tie a 200 g mass to a 2 m string.*
2. *Hold the free end of the string to the ceiling.*
3. *Stretch the “pendulum” out fully. [See diagram below]*
4. *Time how long it takes (to the nearest tenth of a second) for the pendulum to swing to the other side.*
5. *Perform 3 trials and take an average time.*

1a. **200 g Mass** Convert g to kg: \_\_\_\_\_\_\_\_\_ kg

1b. Pendulum Swing Time (to the nearest 0.1 s)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | AverageTime (s) |
| 200 g mass |  |  |  |  |

1c. Label the pendulum to the right using Maximum PE, Maximum KE, PE = KE, maximum velocity, and rest position.

2 m

1d. Calculate the amount of **energy stored** BEFORE the 200 g mass was let go to swing by using mass in kg x gravity in m/s2 x height it falls in meters (mgh). SHOW WORK with UNITS.

1e. Divide the average time it took to make one full swing by two: \_\_\_\_\_\_\_\_\_ s This represents the time it takes for the pendulum to fall to its lowest point with the greatest velocity.

1f. Calculate the highest velocity of the pendulum by using velocity in m/s = distance / time (v = d/t) where distance (d) = 3.14 meters and time (t) equals what you just calculated above in seconds. SHOW WORK with UNITS.

1g. Calculate the amount of **energy in motion** for the 200 g mass at its greatest velocity, using one half the mass in kg times the velocity squared (1/2 mv2). SHOW WORK with UNITS.

1h. Compare the calculated values of the **energy stored** with the **energy in motion**:

**Dropped Ball Procedures & Calculations and Data**



1. *Obtain a tennis ball which mass will be assigned 59 g.*
2. *Measure out 5 m on a string to use for determining the proper distance.*
3. *Go to a school’s bleachers and climb to the top. BE CAREFUL.*
4. *Use the 5 m string to determine where to drop the tennis ball from.*
5. *Drop the tennis ball from the 5 m height and time how long it takes to hit the ground (to the nearest tenth of a second).*
6. *Perform 3 trials and take an average time.*

2a. Mass of the tennis ball: 59 g Convert g to kg: \_\_\_\_\_\_\_\_\_ kg

2b. Time (nearest 0.1 s) it took for the ball to drop 5 meters:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Trial 1 | Trial 2 | Trial 3 | AverageTime (s) |
| Tennis Ball |  |  |  |  |



2c. Label the sketch to the right using Maximum PE, Maximum KE, PE = KE, maximum velocity, and rest position.

2d. Calculate the amount of **energy stored** BEFORE the tennis ball was dropped by using mass in kg x gravity in m/s2 x height it falls in meters (mgh). SHOW WORK HERE with UNITS.

2e. Calculate the highest velocity of the tennis ball by using velocity in m/s = gravity (m/s2) x time (s) where time (t) equals the average time above in seconds. SHOW WORK with UNITS.

2f. Calculate the amount of **energy in motion** for the tennis ball at its greatest velocity, using one half the mass in kg times the velocity squared (1/2 mv2). SHOW WORK with UNITS.

2g. Compare the calculated values of the **energy stored** to the **energy in motion** for the tennis ball:

3. Complete the table below and show work below the table (Include Units)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PE | PE @ 5 m | PE @ 3.75 m | PE @ 2.5 m | PE @ 1.25 m | PE @ 0 m |
| Tennis Ball |  |  |  |  |  |

*PE =*

4. Complete the table below and show work below the table (Include Units)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Velocities | 0 m/s | 5 m/s | 7.1 m/s | 8.7 m/s | 10 m/s |
| Tennis Ball | KE @ 5 m | KE @ 3.75 m | KE @ 2.5 m | KE @ 1.25 m | KE @ 0 m |
| KE |  |  |  |  |  |

V = √(2KE/m) = KE = 1/2 mv2 =

**Conclusions**

Address Hypothesis (*Did the experiment confirm or disprove the hypothesis?*)

Analysis (*optional for this lab*)

1. What do we call the energy that is stored, ready for motion? What equation is used to calculate this type of energy?

2. What do we call the energy of motion? What equation is used to calculate this type of energy?

3. Based on your observations what is the overall relationship between the maximum potential energy and the maximum kinetic energy for either the pendulum or the dropped ball?

4. Show the position where there is maximum Potential Energy” (write: “Max PE”), maximum Kinetic Energy (write: “Max KE”), and equal Potential and Kinetic Energies (write: “Equal PE & KE”) on the drawings below based on your findings.

5. What accounts for the seeming “loss” of energy observed especially in the pendulum swing?

6. What accounts for the seeming “loss” of energy observed especially in the pendulum swing?

7. Compare the PE and KE at each distance from the floor (5m, 3.75 m, 2.5 m, 1.25 m and 0 m). What pattern do you see? Does this give evidence for the conservation of energy?

Errors (*optional for this lab*)

ANSWERS

1a. **200 g Mass** Convert g to kg: **0.2 kg *200 g x 1 kg/1000 g***

1b. Pendulum Swing Time



2 m

|  |  |
| --- | --- |
|  | AverageTime (s) |
| 200 g Mass | **1.5 s** |

1c. Make a sketch to the right of the full swing of your pendulum. Label maximum PE, maximum KE, where PE and KE are about the same, where the greatest velocity exists, & where the two rest positions are for the pendulum.

1d. Calculate the amount of **energy stored** BEFORE the 200 g mass was let go to swing by using mass in kg x gravity in m/s2 x height it falls in meters (mgh). SHOW WORK with UNITS.

 **PE = mgh = (0.2 kg)(10 m/s2)(2 m) = 4.0 J**

1e. Divide the average time it took to make one full swing by two: **0.75 s** This represents the time it takes for the pendulum to fall to its lowest point with the greatest velocity.

1f. Calculate the highest velocity of the pendulum by using velocity in m/s = distance / time (v = d/t) where distance (d) = 3.14 meters and time (t) equals what you just calculated above in seconds. SHOW WORK with UNITS.

 **V = 3.14 m / 0.75 s = 4.2 m/s**

1g. Calculate the amount of **energy in motion** for the 200 g mass at its greatest velocity, using one half the mass in kg times the velocity squared (1/2 mv2). SHOW WORK with UNITS.

 **KE = 1/2 mv2 = ½ (0.2 kg)(4.2 m/s)2 = 1.8 J**

1h. Compare the calculated values of the **energy stored** with the **energy in motion**:

***PE is larger than KE in this case due to friction. If conditions were ideal, PE and KE would be equal.***

2a. Mass of the tennis ball: **59 g** Convert g to kg: **0.059 kg *59 g x 1 kg/1000 g***

2b. Time it took for the ball to drop 5 meters: **t = √(2d/g) = √(2(5 m)/(10 m/s)2) =** **1.0 s**

2c. Calculate the maximum PE of the tennis ball (show work): **2.95 J**

 **PE = mgh = (0.059 kg)(10 m/s2)(5 m)**

2d. Make a sketch to the right of the tennis ball dropping. Label maximum PE, maximum KE, where PE and KE are about the same, where the greatest velocity exists, & where the rest position is.



2e. Calculate the highest velocity of the tennis ball by using velocity in m/s = gravity (m/s2) x time (s) where time (t) equals the average time in seconds. SHOW WORK with UNITS.

 **V = gt = (10 m/s2)(1 s) = 10 m/s**

2f. Calculate the amount of **energy in motion** for the tennis ball at its greatest velocity, using one half the mass in kg times the velocity squared (1/2 mv2). SHOW WORK with UNITS.

 **KE = 1/2 mv2 = ½ (0.059 kg)(10 m/s)2 = 2.95 J**

2g. Compare the calculated values of the maximum **energy stored** to the maximum **energy in motion** for the tennis ball:

***PE and KE are the same. Total Energy = PE + KE.***

3. Complete the table below and show work below the table (Include Units)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| PE | PE @ 5 m | PE @ 3.75 m | PE @ 2.5 m | PE @ 1.25 m | PE @ 0 m |
| Tennis Ball | 2.95 J | 2.21J | 1.48 J | 0.74 J | 0 J |

***PE = mgh (0.059 kg)(10 m/s2)(5 m)***

 ***(0.059 kg)(10 m/s2)(3.75 m)***

 ***(0.059 kg)(10 m/s2)(2.5 m)***

 ***(0.059 kg)(10 m/s2)(1.25 m)***

 ***(0.059 kg)(10 m/s2)(0 m)***

4. Complete the table below and show work below the table (Include Units)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Velocities | 0 m/s | 5 m/s | 7.1 m/s | 8.7 m/s | 10 m/s |
| Tennis Ball | KE @ 5 m | KE @ 3.75 m | KE @ 2.5 m | KE @ 1.25 m | KE @ 0 m |
| KE | 0 J | 0.74 J | 1.48 J | 2.21J | 2.95 J |

V = √(2KE/m) = **√(2[0 J]/0.059 kg)** KE = 1/2 mv2 **= ½ (0.059 kg)(0 m/s)2**

**= √(2[0.74 J]/0.059 kg) = ½ (0.059 kg)(5 m/s)2**

**= √(2[1.48 J]/0.059 kg) = ½ (0.059 kg)(7.1 m/s)2**

**= √(2[2.21 J]/0.059 kg) = ½ (0.059 kg)(8.7 m/s)2**

**= √(2[2.95 J]/0.059 kg) = ½ (0.059 kg)(10 m/s)2**

**Conclusions**

Address Hypothesis

**The hypothesis that if the maximum PE and maximum KE of an object can be calculated, then, maximum PE = maximum KE was confirmed. For the pendulum, maximum PE was 4.0 J, while KE was 1.8 J. The discrepancy can be explained by friction in the pendulum string. For the tennis ball, PE = 2.95 J = KE.**

Analysis

**Potential energy (PE) represents the potential to “fall”, the potential work in the downward direction. Mathematically, PE = mgh, where m is the mass of an object, g is gravity, and h is the height the object may fall. The PE (4.0 J) of the pendulum swing and the resulting KE (1.8 J) were similar, but not the same due to friction at the pivot point.**

**Kinetic energy (KE) is the work done on or by an object in motion based on unbalanced forces acting on the object. Mathematically, KE = ½ mV2, where m is the mass of the object and V is the final velocity of the object. The PE (2.95 J) of the pendulum swing and the resulting KE (2.95 J) were the same since air resistance (friction) was not a factor.**

**The above statements are true because the total energy in a system is the sum of the PE and KE. Mathematically, Etotal = PE + KE. At times PE is Maximum, so KE = 0. At other times KE is maximum, so PE = 0. Therefore max PE = max KE. Most of the time both PE and KE are present, so Etotal = PE + KE.**

1. What do we call the energy that is stored, ready for motion? What equation is used to calculate this type of energy?

 ***Energy that is stored, ready for motion, is called potential energy and is mathematically calculated by the equation: PE = mgh.***

2. What do we call the energy of motion? What equation is used to calculate this type of energy?

 ***Energy of motion, is called kinetic energy and is mathematically calculated by the equation: KE = 1/2 mv2.***

3. Based on your observations what is the overall ideal relationship between the maximum potential energy and the maximum kinetic energy for either the pendulum or the dropped ball?

***The overall ideal relationship between maximum PE and maximum KE is described by the equation: Total Energy = PE + KE. Therefore, maximum PE = maximum KE in an ideal system where friction and air resistance are not taken into consideration.***

4. Show the position where there is maximum Potential Energy” (write: “Max PE”), maximum Kinetic Energy (write: “Max KE”), and equal Potential and Kinetic Energies (write: “Equal PE & KE”) on the drawings below based on your findings.

**Max PE**

**Max KE &**

**max velocity**

 **PE = KE**

**Max PE**

**Max PE**

 **PE = KE**

 **PE = KE**

**Max KE &**

**max velocity**

5. What accounts for the seeming “loss” of energy observed especially in the pendulum swing?

 ***Energy cannot be created or destroyed. Therefore, technically energy is not “lost”, but is transformed (converted into, transferred) into heat because of friction. The pendulum pivot point was the main source of friction in the first experiment of this lab.***

6. What accounts for the seeming “loss” of energy observed especially in the pendulum swing?

 ***Energy is transformed (converted into, transferred) into heat because of friction. The pendulum pivot point was the main source of friction.***

7. Compare the PE and KE at each distance from the floor (5m, 3.75 m, 2.5 m, 1.25 m and 0 m). What pattern do you see? Does this give evidence for the conservation of energy?

 ***The tennis ball dropping gave us evidence for the conservation of energy which can be written as: Total Energy = PE + KE. For example, at the highest point (5 m), PE was 2.95 J and KE was 0. Therefore, total energy was 2.95 J. After dropping to the 3.75 m point, PE decreased to 2.21 J and KE was 0.74, keeping the total energy at 2.95 J.***

Errors

1) Measuring the time for the pendulum to swing 2 m and for the ball to fall 5 m.

2) The actual time measured versus the theoretical time (calculated) may be different.

3) Working with the calculations could intimate students.