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Conservation of Energy and Dissipative Forces

AP Physics C – Mechanics

Night Lab 5

Objective: I can describe how energy can transform from one form to another by describing physical situations in which mech. Energy is converted to other forms and calculating unknown quantities for a system when the object is under the influence of a constant force.

Pre-lab questions

1. List all forces acting on the projectile, before launching it (while the launcher is primed), and after launching the projectile (when the projectile is just fired, at the maximum height of the projectile, and just before it hits the ground). State whether they are conservative or dissipative and why.

   Before: Gravity, Normal. Only gravity is conservative as it converts potential to kinetic
   Instant at Firing: Spring, Gravity, Normal, Spring and Gravity are both conservative forces, converts potential to kinetic
   After: Gravity, (at all points of trajectory, and is also conservative because it is changing gravitational potential to kinetic)
   (Air resistance which is dissipative since it converts kinetic to thermal but is ignored for the purposes of this lab)

2. Describe the different types of energy present at various points in time for the marble as it flies in projectile motion. Include gravitational potential energy, elastic potential energy, kinetic energy, and thermal energy. Indicate the different segments and important points of the experiment, from the compression of the spring to where the object hits the ground. Do this for two cases: one neglecting air resistance, friction, etc., and the other considering air resistance as well.

   No air resistance:
   Before launch – elastic potential energy, gravitational potential energy
   Right after launch – gravitational potential energy, kinetic energy which is all of the elastic potential energy converted
   Right after to peak of launch – gravitational potential energy (increasing), kinetic energy (decreasing)
   Peak of launch – gravitational potential energy (at maximum), kinetic energy (if projectile was not fired straight up)
   Peak to right before object hits ground – gravitational potential energy (decreasing), kinetic energy (increasing), with gravitational potential energy being converted into kinetic energy
   Right before object hits the ground – kinetic energy, where all the energy in original system is now kinetic energy.

   With air resistance:
   Before launch – elastic potential energy, gravitational potential energy
   Right after launch – gravitational potential energy, kinetic energy which is most of the elastic potential energy converted, and some thermal energy lost to friction

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Right after to peak of launch – gravitational potential energy (increasing), kinetic energy (decreasing), more thermal energy due to air resistance
Peak of launch – gravitational potential energy, kinetic energy (if projectile was not fired straight up), thermal energy from air resistance
Peak to right before object hits ground – gravitational potential energy (decreasing), kinetic energy (increasing), with gravitational potential energy being converted into kinetic energy, thermal energy
Right before object hits the ground – kinetic energy, thermal energy

Procedure

Constant: launch height (0.904 m), mass of projectile (0.0164 kg)

Measured: time taken for projectile to reach the ground (s), horizontal distance traveled by the ball before it hit the ground

Also kept track of the displacement of the spring for each trial.

Data

Projectile mass: 0.0164 kg

Displacement of spring (m)	Displacement^2 (m^2)	Measured Time (s)	Launch Distance (m)	Launch Height (m)	Calculated Time (s)	Velocity (m/s)	Velocity^2 $\left(\frac{m}{s}\right)^2$	mv^2 $(kg\left(\frac{m}{s}\right)^2)$
	0							0
0.038	0.001444	0.35	1.34	0.904	0.303564	4.414231	19.4854381	0.319561
0.038	0.001444	0.38	1.33	0.904	0.303564	4.381289	19.1956958	0.314809
0.051	0.002601	0.56	1.785	0.904	0.303564	5.880151	34.5761806	0.567049
0.051	0.002601	0.43	1.765	0.904	0.303564	5.814267	33.8057049	0.554414
0.069	0.004761	0.40	2.45	0.904	0.303564	8.070796	65.1377489	1.068259
0.069	0.004761	0.46	2.28	0.904	0.303564	7.510782	56.4118407	0.925154

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Results

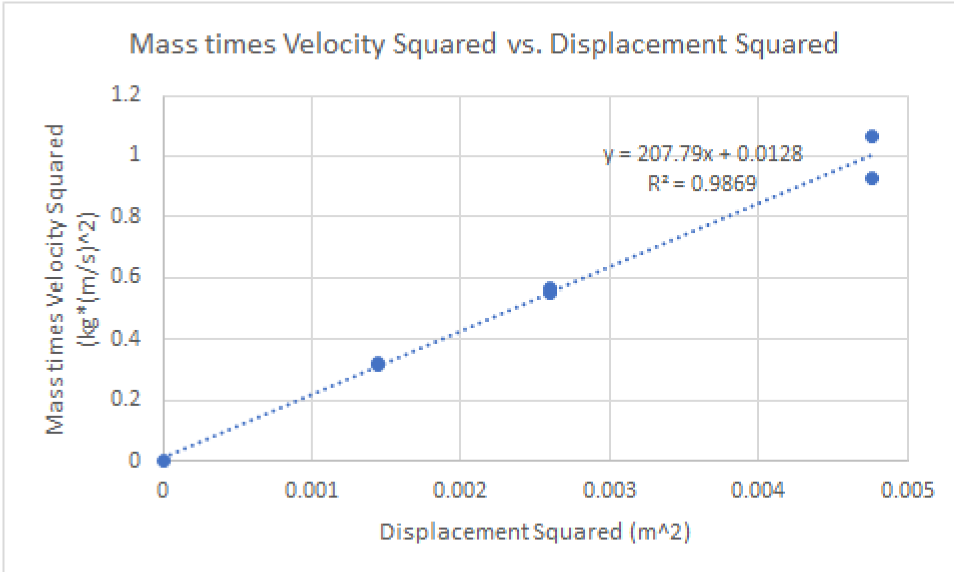

Figure 1. Graph of mv^2 vs. Δx^2

Note: All units are standard SI units

Conservation of energy: $\frac{1}{2}k\Delta x^2 = \frac{1}{2}mv^2$, where k is the spring constant, Δx is the displacement of the spring, m is the mass, and v is the horizontal velocity

To calculate velocity: $v = \frac{d}{t}$ where d is the horizontal displacement of the projectile and t is the time taken for the projectile to reach the ground

To calculate time: $h = \frac{1}{2}gt^2$, h is initial height, g is gravitational acceleration

$$\frac{1}{2}k\Delta x^2 = \frac{1}{2}m\left(\frac{d}{t}\right)^2$$

Thus, k is equal to the slope of the graph for mv^2 vs. Δx^2

$$k = 207.79\ kg/s^2$$

After linearization, the graph shows a direct linear correlation between mass times velocity squared vs displacement squared. The R^2 value is very high suggesting that our data was fairly accurate, aside from the slight difference when using the 3rd spring setting. As shown in the calculations, the slope of this graph is the spring constant k. This can be seen from the theoretical fact that ½ kx^2 = ½ m(d/t)^2 so mv^2 = kx^2.

Analysis Questions

1. Quantitatively, how does the total energy of the ball-launcher-Earth system (just say everything except the air) before launch compare to right after the projectile is launched? To the highest

point in the trajectory? Right before the projectile hits the ground? Neglect air resistance and friction.
The total energy of the ball-launcher-Earth system remains constant throughout the entire motion of the projectile; the different forms of energy are just converted to one another during the trajectory.

2. What is the work done by friction in the launcher, in the real world (0 or non-zero)? How would this affect the range of the marble compared to if there was no friction?
In the real world, work done by friction in the launcher is non-zero. This would decrease the range of the marble because the total energy decreases (friction causes thermal energy to be released).
3. What percentage of the initial total energy is transformed to thermal energy due to work done by the air (calculate the work done by air resistance)? Neglect friction between the launcher and marble, and use conservation of energy.
    a. Should this be significant for the provided projectile? Why/why not?
    SKIP
4. List two main sources of error from the lab, where they came from, and how to further minimize them in the future.
One source of error was not being able to accurately measure the range of the marble, as we had to eyeball where it hit the ground. We can minimize this in the future by incorporating something that would leave a mark where the marble hit the ground, such as by covering the marble in ink or using sand so it would create a dent.
Another source of error was potentially measuring inaccurate times because it was difficult to correctly time the short period from when the marble was released to when it hit the ground. We can minimize this in the future by starting from a greater height, allowing us to have more time to react and stop the timer. Additionally, having a greater time will decrease the margin of error in proportion to the actual time in the air.
5. **5 Daily E.C. Points:** Look up the formula for magnetic force for a current-carrying wire and the magnetic field of a solenoid. Given 100 turns of coil (about 1 m of coil) with a current of 0.005 A, and a cross-sectional area of 0.75 in^2, compute the force needed to launch a projectile of the same mass as your projectile through a 6'' solenoid at 2 m/s. Use the spring constant to determine the displacement of the spring from equilibrium. Show all work.

Force acting on the solenoid: $F = ILB$, where I is the current (A), L is the length of the coil (m), B is the magnetic field of the coil
Magnetic field of solenoid:
$$B = \mu_0 \frac{N}{l} I = 4\pi \times 10^{-7} \cdot \frac{100}{6 \cdot 0.0254} \cdot 0.005 = 4.123 \times 10^{-6} A \cdot H \cdot m^{-2}$$
Where μ_0 is the magnetic constant ($H \cdot m^{-1}$), $\frac{N}{l}$ is the number of turns per unit length. Then,
$$F = 0.005 \cdot 1 \cdot B = 2.06 \times 10^{-8}\, N$$

Then, using conservation of energy and assuming the magnetic force does negative work on the spring (if it is positive work, add instead),

$$\frac{1}{2} k \Delta x^2 - F \Delta x = \frac{1}{2} m v^2$$

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$$\frac{1}{2} \cdot 207.79 \cdot \Delta x^2 - 2.06 \cdot 10^{-8} \cdot \Delta x = \frac{1}{2} \cdot 0.0164 \cdot 2^2$$

$$\Delta x = 0.0178\ m$$