

LAB VIII. CONSERVATION OF ENERGY

1. Objectives

This experiment focuses on studying the projectile motion and the friction experiment through energy analysis. The setups would be identical to **Lab II** and **Lab IV**, but emphasis is on finding potential and kinetic energy and calculate the energy loss due to friction force.

2. Material (see **Fig. 1**)

- Hockey puck or a sliding object
- Meter stick/ruler
- Scale (Kitchen scale)
- Tape
- Wooden/metallic surface

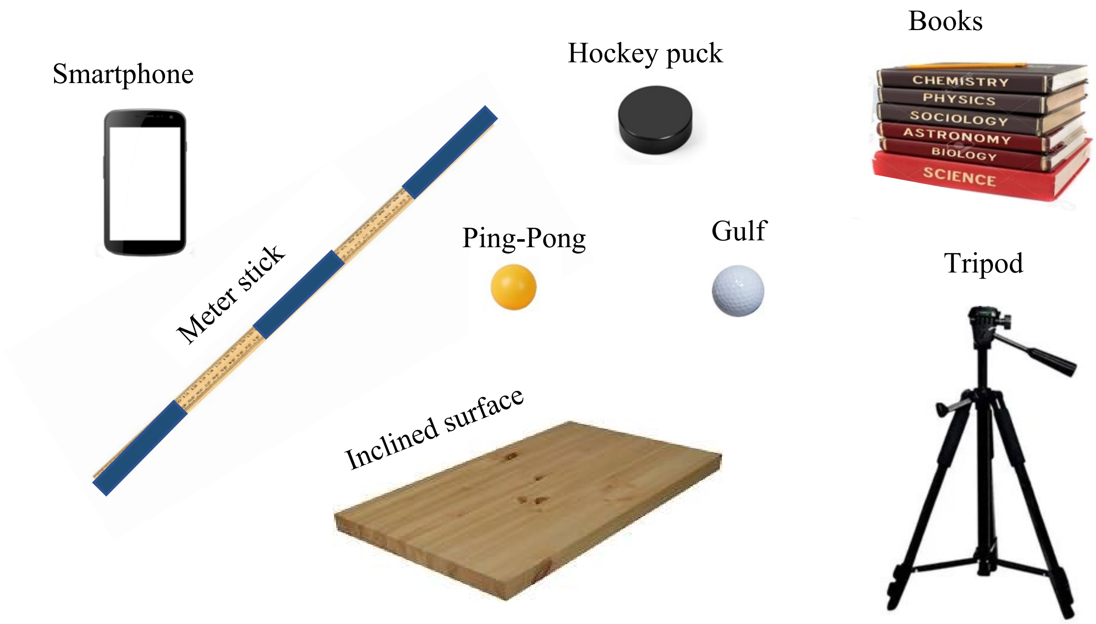

Fig. 1: An example list of materials used in this lab.

3. Theory

3.1 Kinetic and Gravitational Potential Energy

An object with a mass m, with a nonzero magnitude of velocity v has a kinetic energy,

$$K = \frac{1}{2}mv^2. \tag{1}$$

Due to the gravity of the earth, an object at a specific height h has the potential energy,

$$U = mgh, \tag{2}$$

where h is the relative height of the object with respect a reference. So, the magnitude and sign of the potential energy depends on the selected reference.

3.2 Conservation of Energy

In absence of any dissipative energy including friction or air resistance, the total energy of a system would be the summation of kinetic and potential energy. At any time, the total energy is a constant,

$$E = K_i + U_i = K_f + U_f, \tag{3}$$

where i and f are two different time instances. **Equation. 3** can be extended to systems with more than one particle and remains valid. For a system of one particle, using **Eq. 1** and **2**,

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f. \tag{4}$$

3.3 Work and Energy theorem

In general, it can be proved that for any system, the change in kinetic energy would be the same as the work W done on the system,

$$\Delta K = W. \tag{5}$$

For a system only subject to gravity with no dissipative forces, the total work is equal to the negative of the change in gravitational potential,

$$W = -\Delta U = mg(h_i - h_f). \tag{6}$$

Plugging **Eq. 6** into **Eq. 5** results in,

$$\Delta K + \Delta U = \Delta E = 0, \tag{7}$$

which implies that total energy is conserved. However, in the presence of *dissipative* forces, for example friction, the work would be,

$$W = mg(h_i - h_f) - f_k d, \tag{8}$$

where f_k is the friction force and d is the displacement of the object. Combining **Eq. 8** and **5** results in

$$\Delta E = -f_k d. \tag{9}$$

Therefore, friction cause some energy loss resulting in a final energy that is smaller than initial energy. The negative sign of the work by friction is because friction and displacement are in opposite direction (see **Fig. 2**).

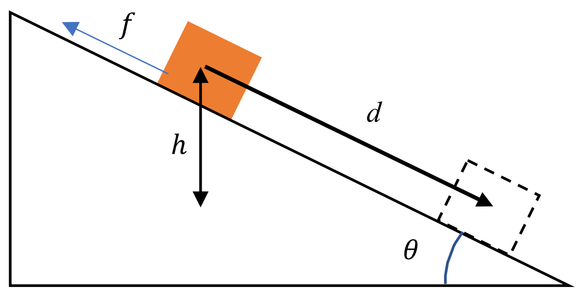

Fig. 2: Downward movement of the block by distance d, in presence of friction force f.

4. Lab Setup Preparation

You will analysis the tracking done at two experiments done before:

(1) **Projectile motion** video (https://www.youtube.com/watch?v=67j4kJOiAQI)

(2) **Friction** video (https://www.youtube.com/watch?v=nHfeejFBe28)

Prior to this experiment, you need have analyzed both of those experiments. Later on, there are questions that on your results from those experiments.

A detailed YouTube video is available to show you the exact procedure on how to analyze energy in Tracker.

https://www.youtube.com/watch?v=NnOquOM69LU

5. Experiment & Data Analysis Procedure

5.1 Projectile motion

5.1.1 *Loading old files*: Load the Tracker analysis files done for projectile motion

5.1.2 *Total velocity*: Find the total velocity of the system as a function of time.

5.1.3 *Mass*: Set the correct mass of the object and find the kinetic energy as a function of time.

5.1.4 *Coordinate system*: Put the coordinate system at the surface of the table

5.1.5 *Gravitational potential*: Find the gravitational potential energy as a function of time and plot it.

5.1.6 *Reference*: Change the reference of the coordinate system and find the kinetic and potential energy values again. Do they depend on the choice of the coordinate system? Explain using **Eq. 1** and **2**.

5.1.7 *Total energy*: Find the total mechanical energy according to **Eq. 3**. Do you observe the conservation of energy for your system? Think of dissipative force as well as calibration problems that can cause errors.

5.2 Friction (Sliding downward)

5.2.1 *Plot the energies*: Follow steps 5.1.1 to 5.1.3. Plot the kinetic and potential energy as a function of time. Choose the bottom of the incline plane as the reference.

5.2.2 *Work energy theorem*: Use the definition of the kinetic and potential energy and define the work energy theorem (**Eq. 9**) in the Tracker app in terms of height, final and initial velocity. Please refer to the instruction video of this lab to learn how to define new functions.

5.2.3 *Work by friction*: Find the work done by friction using the kinetic friction coefficient in evaluated in Friction lab.

5.2.4 *Different angles*: Verify the work energy theorem for at least 5 different trials. Each trial should be done at different incline plane angles.

5.3 Friction (sliding upward)

5.3.1 *Load the correct files*: Make sure the object is initially stationary at the bottom of the incline plane. Then a small kick led to upward movement of the object.

5.3.2 *Work energy theorem*: Write down the work energy theorem in terms of in terms of height, final and initial velocity. Discuss how different it is compared to 5.2.2

5.3.3 *Different angles*: Verify the work energy theorem for at least 5 different trials. Each trial should be done at different incline plane angles.

5.3.4 *Sources of error*: Think of sources of error involved in both friction and projectile motion analysis. How can you improve your analysis.

Lab VIII Worksheet

Name of the Student: ______________________ **Date: _____________________**

Q.1 Projectile motion

Please use your saved files from the projectile motion experiment. You can open the trz type format files that includes all your tracking.

Q.1.1 What is the expression for total velocity v in terms of v_x and v_y.

Q.1.2 Plot the kinetic energy as a function of time.

Q.1.3 Plot the potential energy as a function of time.

Q.1.4 Change the reference of the coordinate system. Does kinetic and potential energy changes? Explain.

Q.1.5 Plot the total mechanical energy, as well as kinetic and potential energy in a single graph. How does the mechanical energy changes? Explain

Q.1.6 What can cause the violation of conservation of energy? Name at least two possible sources.

Q.2 (downward motion)

Set the reference of your data analysis in Tracker at the bottom of the incline surface.

Q.2.1 Plot the kinetic energy, potential energy and the sum of them in one graph for one trial (as you did in section 6.1). Explain each of them changes ats a function of time.

Q.2.2 Write the equations for total mechanical energy change and work done on the system.

Q.2.2 Estimate the work done by the friction (Use the kinetic friction coefficient evaluated in the Friction experiment) for one trial and plot as a function of time.

Q.2.3 Discuss the dependence of work on the time.

Q.2.4 Verify the work energy theorem in the table below. Find the difference and normalized it in terms of the total change in the potential energy ($\Delta U = mg(h_f - h_i)$)

Trials	W	ΔE	$W - \Delta E$	$\frac{W - \Delta E}{\Delta U}$
1				
2				
3				
4				
5				

Q.3 Friction (upward motion)

Q.3.1 Write down the initial and final mechanical energy according to eq. (1) to (4). Then, write down work energy theorem.

Q.3.2 Verify the work energy theorem for 5 different trials as in 6.2.4

Trials	W	ΔE	$W - \Delta E$	$\frac{W - \Delta E}{\Delta U}$
1				
2				
3				
4				
5				

Q.3.3 Does your results confirm the work energy theorem? What are the sources of error?

Q.3.4 Discuss possible ways to improve the experiment.