1-2022

Experiment 1.05: Energy

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I. EXPERIMENT 1.05: ENERGY

A. Abstract

A body slides down a frictionless inclined surface. The total energy of the body is calculated at several stages during the fall and examined for constancy.

B. Formulas

$$KE = \frac{1}{2}mv^2 \tag{1}$$

$$U_g = mgy \tag{2}$$

where Eq. (2) is the gravitational potential energy for a body of mass m near the surface of the earth.

C. Description and Background

Consider an object of mass, m, moving with speed, v. Its translational kinetic energy is defined to be

$$KE = \frac{1}{2}mv^2$$

Gravity, being a conservative force, has a potential energy that depends only on configuration, and, in the particular setting of this experiment, on the position of the object relative to the earth. If an object is lifted from a height y_1 to a height y_2, its change in gravitational potential energy is defined to be

$$\Delta U_g = mg\left(y_2 - y_1\right) = mg\Delta y$$

where

$$U_g = mgy$$

is the gravitational potential energy at position (altitude) y, measured with respect to an arbitrary origin (the zero level of potential energy). Because the dependence is only on altitude, the change in gravitational potential energy in dropping a box to the ground, for example, is the same as if it slides down a ramp.

Define the total mechanical energy of a system as the algebraic sum of the kinetic and potential energies

$$E = KE + U$$

In the absence of dissipative forces, such as friction, the total mechanical energy of a system neither increases nor decreases in a process; it remains constant. In such cases, mechanical energy is conserved. This is expressed as

$$E_2 = E_1$$

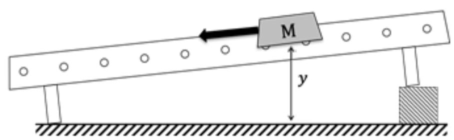

FIG. 1. Body sliding on an inclined air-track.

In this experiment, you will use an inclined air track and measure the speed along the incline as well as the height above the table (Fig. 1) of a descending glider. The speeds will

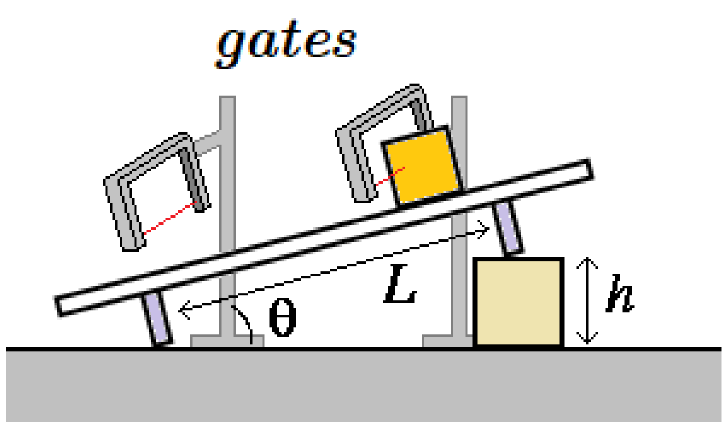

FIG. 2. Schematic depiction of the air track set-up.

be determined using two photogates positioned along the air track (Fig. 2). By noting the

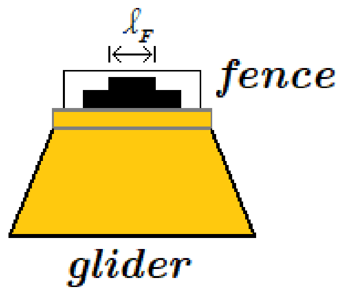

FIG. 3. Glider with flag/fence.

length, ℓ_F, of the (opaque) "flag," or "fence," attached to the glider (Fig. 3), and the time of the gate's light-beam obstruction, the speeds are calculated as

$$v_{A,B} = \frac{\ell_F}{t_{A,B}}$$

These measurements will allow one to find the kinetic, potential, and total mechanical energy at two locations in the glider's path. This will be used to examine the conservation of mechanical energy in the glider's motion.

D. Procedure

1. Position the two photogates at two locations, A and B, along the air track.
2. Make sure the photogates are positioned properly so the fence on the glider blocks the gates' light beams.
3. Because the potential energy is arbitrary, the vertical location of anything mirroring that of the glider's can serve as y in (2). There is a guy-wire, which runs the length of the air track, whose vertical location above the table at the position of the photogates can easily be measured with a meterstick to the millimeter. Record these vertical locations above the table at positions A and B along the air track ($y_{A,B}$).
4. Identify a position on the track (before photogate A) from which to repeatably release the glider from rest.
5. After releasing the glider, it will pass through the gates, and it will bounce off the end of the track, so make sure it does not run through the second gate again.
6. Record the two time intervals (A and B) from the CPO timer. Repeat this procedure several times.

Nota Bene: The transparent parts of the fence attachement must be free of smudges or marks that could obstruct the photogate beams after the opaque strip has. An indication that this may have occurred is an anomalously short time reading for either t_A and/or t_B.

E. Measurements

glider mass, m [$gram$]	
fence length, ℓ_F [cm]	
location A above table: y_A [cm]	
location B above table: y_B [cm]	

Time Intervals		
Trial	t_A [sec]	t_B [sec]
1		
2		
3		
4		
5		

F. Instructions

1. Calculate the kinetic energy and gravitational potential energy of the glider based the measurements. Add these to determine the total energy:

$$E_{\text{total}} = \frac{1}{2}mv^2 + mgy \tag{3}$$

2. Assuming conservation of energy, any variation in the total energy is random, so the mean should be a good estimate for the theoretical value. Calculate the mean energy, $\bar{E}_{\text{total}}$, in Joules.

3. What is the standard error, $\delta\bar{E}_{\text{total}}$, associated with the previous calculation?

4. For location A, calculate the uncertainty in the total energy, $\delta E_{A,}$ using the following (propagated error) formula

$$\delta E^2 = \left(KE^2 + U_g^2\right)\left(\frac{\delta m}{m}\right)^2 + 4KE^2\left[\left(\frac{\delta\ell_F}{\ell_F}\right)^2 + \left(\frac{\delta t}{\bar{t}}\right)^2\right] + U_g^2\left(\frac{\delta y}{y}\right)^2 \tag{4}$$

taking $\delta m = 0.1\ g,\ \delta\ell_F = 0.02\ cm,\ \delta t = 0.0001\ sec$, and $\delta y = 0.3\ cm.$

5. For location B, calculate the uncertainty in the total energy, $\delta E_{B,}$ using (4).

6. Do the two intervals, $(E_A - \delta E_A,\ E_A + \delta E_A)$ and $(E_B - \delta E_B,\ E_B + \delta E_B)$ overlap?

7. What does the answer to the question above imply about conservation of energy?

G. Calculations

location	$\bar{t}$ [sec]	$v = \ell_F \,/\, \bar{t}$ [m/s]	KE [J]	U_g [J]	E_{total} [J]
A					
B					

$\bar{E}_{\text{total}}$ [$Joules$]	
$\delta\bar{E}_{\text{total}}$ [$Joules$]	
δE_A [$Joules$]	
δE_B [$Joules$]	
$(E_A - \delta E_A,\ E_A + \delta E_A) \cap (E_B - \delta E_B,\ E_B + \delta E_B)$	

Answer to 7 above: