Exercise 7: Work and kinetic energy

Purpose: To study the relationship between the work done on an object and its change in kinetic energy.

Introduction

Energy can be transferred into different forms such as an electric toothbrush that changes electrical energy into vibrational energy, or a gas engine which changes chemical potential into rotational energy. For a constant force with magnitude F the work performed on an object moving in a straight line a distance d at an angle of α relative to the direction of the constant force is given by

$$W = Fd\cos\alpha.$$

The external work done on a system is equal to the change in the kinetic energy and potential energies of the system ($\Delta K =$ change in the kinetic energy, $\Delta U_g =$ change in gravitational potential energy, $\Delta U_g =$ change in a spring's potential energy, $\Delta U_{\text{int}} =$ change in the internal energy of the system, …),

$$W_{\text{ext}} = \Delta K + \Delta U_g + \Delta U_s + \Delta U_{\text{int}} + \cdots.$$

When mechanical energy is conserved, *i*.e., there is no external work performed on the system, no heat is added to or removed from the system, and there is no change in the internal energy of the system, we may simply write

$$0 = \Delta K + \Delta U_{\text{mech}},$$

where ΔU_{mech} is the change in the mechanical potential energies such as ΔU_s and ΔU_g.

When mechanical energy is conserved, it does not mean that work is no longer being performed internally. For example, there can be a net change in gravitational potential, which means that work has been on one the object by gravity. This work done by gravity, of course, speeds up (falling) or slows down (slowing after being thrown upward) an object. If there is only the gravitational potential present (no springs and other sources of storing potential energy), then the change in gravitational potential energy must be converted to kinetic energy. This is based on the work-kinetic energy theorem, which states that the net amount of work done on an object is equal to the change in its kinetic energy,

$$W_{\text{net}} = \Delta K.$$

In this experiment, a glider starting from rest on an air track is attached to a string. The string is drawn over a pulley with a mass hanger tied to the other end. Work is done by gravity which results in a gain of kinetic energy of the entire system.

Laboratory assignment

1. Place the glider on the air track and turn it on.
2. Level the air track by increasing decreasing one end of the track until it is as close to level as you can achieve.
3. Tie one end of the string to the glider and the other end to the hanger and place the sting over the pulley.
4. Click the motion sensor to the air track at the opposite end of the pulley and start the software.
5. Select the distance and speed measurements.

6. Hang 20 g of mass on the end of the hanger while holding the cart about 40 cm away from the motion sensor.
7. Click run on the Capstone PASCO software and click on the “graph and table” icon.
8. Set three columns to record the time, position, and velocity, and set the graph to display the velocity as a function time.
9. Change the data collection rate to 50 Hz.
10. Then release the glider after data begins to record. Be sure to remove your hand quickly and keep it out of the path of the motion sensor!
11. If there is a big dip in the velocity data at a specific position, then please ask for assistance.
12. Highlight the relevant velocity data (immediately before the glider was released until <u>just before</u> the masses hit the floor).
13. Export the distance and velocity data as a function of time.
14. The total system (glider + hanger + masses) is moving with a velocity given by the velocity data you exported. Calculate the change in kinetic energy of the system relative to the initial kinetic energy (zero kinetic energy relative to the motion sensor when starting from rest) at each time the velocity was taken. This should be done in excel to be used for a graph requested later.
15. For a level track, the only change in gravitational potential energy occurred from the height change in the mass hanger. Calculate the work done by gravity on the mass hanger at each time the distance was recorded relative to the initial displacement (note that $W_g = -\Delta U_g$). This should be done in excel to be used for a graph requested later.
16. Graph the work done by the force of gravity and the change in the glider’s and hanger’s kinetic energy as a function of time <u>on the same graph</u>.
17. State how well they overlap?
18. State some possible sources of error.
19. Choose a time just before you stopped the glider. Take the percent difference between the work done by the gravitational force and the change in kinetic energy, $\%\ \mathrm{diff} = \left(\frac{W_g - \Delta K}{W_g}\right) \cdot 100\%$.

Equipment list: air track, glider, ring stand, mass hanger set, string, pulley, motion sensor, laptop.