Laboratory 10: Conservation of Energy – Prelab

1 Cart attached to a suspended mass

A 0.600 kg cart can slide along a horizontal frictionless track as illustrated in Fig. 1. The cart is attached to a 0.200 kg suspended masspiece, which is released from rest at a height of 0.60 m above the floor. These are released and the suspended masspiece eventually hits the floor. Consider the motion from when the cart is released until just before the suspended masspiece hits the floor.

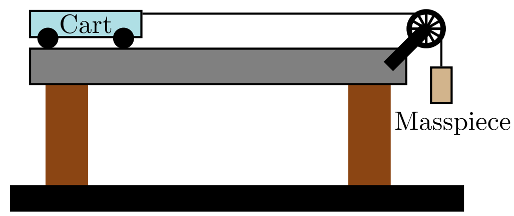

Figure 1: Cart and suspended masspiece.

a) Determine the change in gravitational potential energy of the cart, $\Delta U_{\text{grav cart}}$, the change in gravitational potential energy for the masspiece $\Delta U_{\text{grav susp}}$, and the change in kinetic energy for the entire system ΔK_{total}.

b) Determine the speeds of the cart and the masspiece just before the masspiece hits the ground.

Laboratory 10: Conservation of Energy – Activity

The mechanical energy of a physical system obeys

$$\Delta E = W_{\text{nc}} \tag{1}$$

where $\Delta E = E_f - E_i$ is the change in mechanical energy from an initial instant to a final instant and W_{nc} is the work done by all the non-conservative forces between these instants. If $W_{\text{nc}} = 0$ then

$$\Delta E = 0. \tag{2}$$

and thus $E_f = E_i$. This is the law of conservation of energy.

In this experiment, you will consider energy conservation for the system illustrated in Fig. 2. The cart and suspended masspiece will be released from rest and allowed to accelerate until the suspended masspiece hits the floor. The task will be to determine the change in total energy from the moment of release (the *initial* moment) to the moment just before the suspended masspiece hits the floor (the *final* moment).

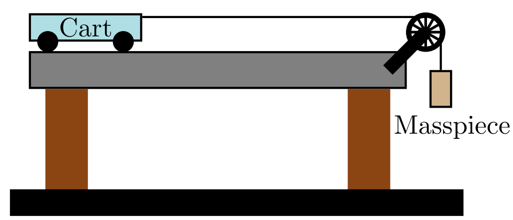

Figure 2: Cart and suspended masspiece.

Here, the mechanical energy of the system is

$$E = K_{\text{total}} + U_{\text{grav total}} \tag{3}$$

where K_{total} is the kinetic energy of *all parts of the system* and $U_{\text{grav total}}$ is the gravitational potential energy of *all parts of the system* at any single moment. It can be shown that, ideally in this situation, $W_{\text{nc}} = 0$ and thus $\Delta E = 0$. Then Eq. (3) implies that conservation of energy is equivalent to

$$\boxed{\Delta K_{\text{total}} = -\Delta U_{\text{grav total}}} \tag{4}$$

where

$$\Delta K_{\text{total}} = K_{\text{total}\, f} - K_{\text{total}\, i} \tag{5}$$

$$\Delta U_{\text{grav total}} = U_{\text{grav total}\, f} - U_{\text{grav total}\, i}. \tag{6}$$

Various measurements enable calculation of the energies involved, and ultimately the conservation of mechanical energy, via Eq. (4) can be checked.

1 Theory and Experimental Design

The cart and suspended masspiece will be released from rest. Recall that the version of energy conservation that we aim to check is $\Delta K_{\text{total}} = -\Delta U_{\text{grav total}}$ over the period between initial and final instants. Consider first, the gravitational potential energy.

a) Use Eq. 2 and Eq. 3 to derive Eq. 4.

b) Describe how to determine a numerical value for $\Delta U_{\text{grav total}}$. Your description should include a *list* of the quantities that you need to measure (e.g. which mass is involved, etc,. . .) and a procedure for calculating $\Delta U_{\text{grav total}}$ from these measured numbers.

Now consider the kinetic energy.

c) Is ΔK for the cart positive, negative or zero?

d) Is ΔK for the masspiece positive, negative or zero?

e) Describe how to determine a numerical value for ΔK_{total}. Your description should include a *list* of the quantities that you need to measure (e.g. which mass is involved, etc,. . .) and a procedure for calculating ΔK_{total} from these measured numbers.

f) Describe how you will use measured values for ΔK_{total} and $\Delta U_{\text{grav total}}$ to check energy conservation.

g) You will need to measure the velocity of the cart at the instant before the suspended masspiece hits the floor. Explain, using *physics,* why it is sufficient to measure the velocity of the cart *after* the masspieces have hit the floor.

h) You will be given a cart, suspended masspieces and an electronic timer which can measure the speed of the cart. Briefly describe how you could use these to construct an experiment to verify that the mechanical energy is conserved in the scenario considered here.

2 Experiment

a) Level the track and adjust the pulley so that the string runs horizontally and freely.

b) Attach the photogate trigger (Plexiglas sheet with black stripes) to the cart and check, by running it through the photogate, that the detector is triggering on the 5 cm long black strip.

c) Place the photogate so that it triggers shortly *after the moment at which the suspended masspiece has hit the floor.*

d) Open Capstone, and connect the photogate using One photogate single flag. Arrange a digits window to display Time in Gate. This will display the time that the black strip takes to pass through the photogate.

e) Hold the cart at rest near the end of the track opposite the pulley. Measure the distance from the base of the masspiece hanger to the floor. Start the photogate timer, release the cart and record the duration for which the black strip interrupted the photogate. *It may be a good idea to catch the cart after the cart passes through the photogate to prevent the cart from bouncing off the track stop and passing through the photogate a second time.* Use your measured time to calculate the final speed of the cart.

f) Calculate ΔK_{total} and $\Delta U_{\text{grav total}}$. Describe whether the magnitudes of these are the same, approximately the same, or substantially different. To get an idea of the size of the discrepancy between them, determine the percentage difference via

$$\frac{|\Delta K_{\text{total}}| - |\Delta U_{\text{grav total}}|}{|\Delta U_{\text{grav total}}|} \times 100\%.$$

g) Repeat parts e) and f) for two additional different suspended masses.

3 Conclusion

a) What does this experiment establish concerning mechanical energy?

b) Explain any discrepancies between your observations and the theoretical predictions. For your explanation you should consider:

   i) How accurately you were able to measure the quantities needed to carry out the calculations.

   ii) Whether there are any forces present that were not included in the energy analysis.

   iii) Whether there were any objects in the experiment whose motion was not included in the analysis.

4 Exercises

a) Consider an experiment of the type above where the mass of the cart is 1000 g and the mass of the suspended masspiece is 275 g. The suspended masspiece is dropped from a distance of 45 cm above the floor. Determine $\Delta U_{\text{grav total}}$ and use this to determine the speed of the cart at the instant just before the hanger hits the floor. Assume that there is no friction and ignore the pulley.

b) An experiment of the type done in this lab is carried out for a situation where $m_{\text{cart}} = 800\,\text{g}, m_{\text{susp}} = 200\,\text{g}$ and the masspiece is dropped through height 50 cm. The photogate records the duration of passage of the 5.0 cm black band as 0.040 s. Determine ΔK_{total} and $\Delta U_{\text{grav total}}$. The experiment is repeated, this time giving the duration of passage of the black band as 0.038 s. Fill out the following table.

	Time	ΔK_{total}	$\Delta U_{\text{grav total}}$	percentage difference
Exp 1	0.040 s			
Exp 2	0.038 s			

Table 1: Question b).

For approximately how much of the percentage difference is the discrepancy in the timing responsible? How would this enter into the discussion of the discrepancies in your experiment?