Flipping Physics Lecture Notes:

2012 #2 Free Response Question
AP Physics C: Mechanics - Exam Solution
http://www.flippingphysics.com/apcm-2012-frq2.html



This Experimental Design Question also works as a part of the AP Physics 1 curriculum.
(It does not have any calculus in it, eh!)

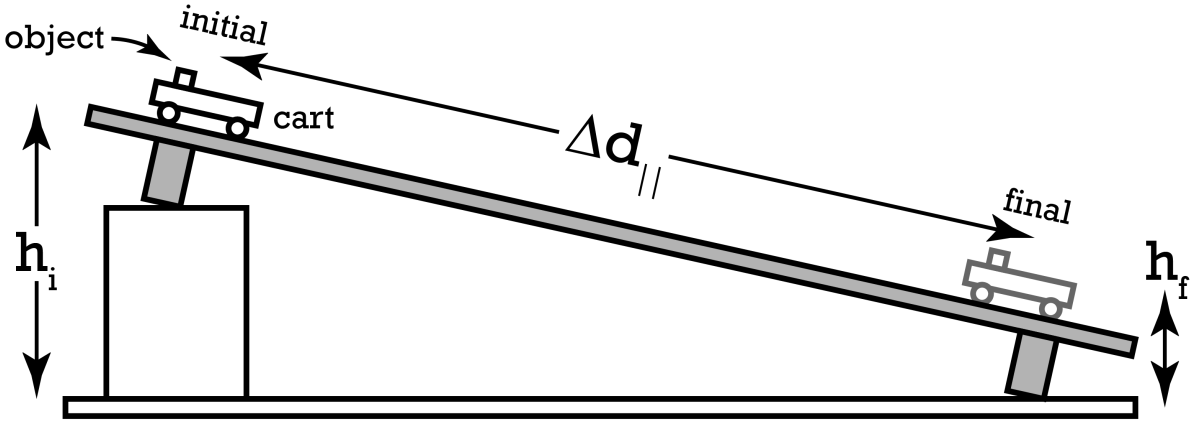
*There are many correct solutions to this question. I will provide two complete, independent solutions, because, you know, why not?*

You are to perform an experiment investigating the conservation of mechanical energy involving a transformation from initial gravitational potential energy to translational kinetic energy.

(a) You are given the equipment listed below, all the supports required to hold the equipment, and a lab table. On the list below, indicate each piece of equipment you would use by checking the line next to each item.

| | | |
|---|---|---|
| X Track | X Meterstick | X Set of objects of different masses |
| X Cart | X Electronic balance | ____ Lightweight low-friction pulley |
| ____ String | X Stopwatch | |

(b) Outline a procedure for performing the experiment. Include a diagram of your experimental setup. Label the equipment in your diagram. Also include a description of the measurements you would make and a symbol for each measurement.




- *Use the electronic balance to measure the mass of the cart, $m_c$ and the mass of the objects, $m_o$ .*
- *Incline the track at an angle.*
- *Place the cart near the top of the track and measure the initial height of the cart above the table, $h_i$ .*
- *Identify a location near the end of the rack as the final point for the cart. Measure the final height of the cart above the table, $h_f$ .*
- *Measure the distance the cart will travel on the track, $\Delta d_{||}$ .*
- *Let go of the cart without giving it an initial velocity. Therefore, the cart has no initial velocity, $v_i = 0$.*
- *Measure the time, $\Delta t$, it takes the cart to travel the distance $\Delta d_{||}$ .*
- *Repeat 9 times with different known mass combinations placed in the cart.*
- *The total mass of the cart and objects in the cart is $m_t$ .*

(c) Give a detailed account of the calculations of gravitational potential energy and translational kinetic energy both before and after the transformation, in terms of the quantities measured in part (b).

- *The horizontal zero line is at the top of the table.*
- *Gravitational Potential Energy initial:* $$PE_{gi} = m_t g h_i$$
- *Gravitational Potential Energy final:* $$PE_{gi} = m_t g h_i$$
- *Kinetic Energy initial:* $$KE_i = \frac{1}{2} m_t v_i^2 = \frac{1}{2} m_t \left(0\right)^2 = 0$$
- *To determine Kinetic Energy final, we need the final velocity of the cart. Use the Uniformly Acceleration Motion equation* $$\Delta d_{\parallel} = \frac{1}{2}\left(v_i + v_f\right)\Delta t = \frac{1}{2}\left(0 + v_f\right)\Delta t \Rightarrow v_f = \frac{2\Delta d_{\parallel}}{\Delta t}$$
- *Kinetic Energy final:* $$KE_f = \frac{1}{2} m_t v_f^2 = \frac{1}{2} m_t \left(\frac{2\Delta d_{\parallel}}{\Delta t}\right)^2 = \frac{2 m_t \Delta d_{\parallel}^2}{\Delta t^2}$$

(d) After your first trial, your calculations show that the energy increased during the experiment. Assuming you made no mathematical errors, give a reasonable explanation for this result.

*It is difficult to let go of anything without accidentally pushing it. Perhaps you gave it an initial velocity. This would increase the initial kinetic energy above the zero assumed in our calculations.*

(e) On all other trials, your calculations show that the energy decreased during the experiment. Assuming you made no mathematical errors, give a reasonable physical explanation for the fact that the average energy you determined decreased. Include references to conservative and nonconservative forces, as appropriate.

*Nonconservative forces such as friction likely converted some of the mechanical energy to heat and sound, and therefore decreased the kinetic energy measured at the bottom of the track.*

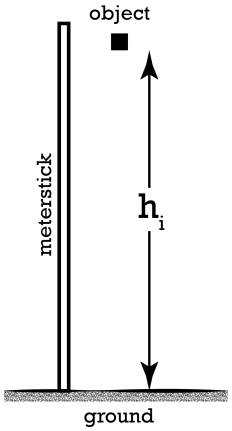
And now a completely different solution:

You are to perform an experiment investigating the conservation of mechanical energy involving a transformation from initial gravitational potential energy to translational kinetic energy.

(a) You are given the equipment listed below, all the supports required to hold the equipment, and a lab table. On the list below, indicate each piece of equipment you would use by checking the line next to each item.

| | | |
|---|---|---|
| ____ Track | __X__ Meterstick | __X__ Set of objects of different masses |
| ____ Cart | __X__ Electronic balance | ____ Lightweight low-friction pulley |
| ____ String | ___X__ Stopwatch | |

(b) Outline a procedure for performing the experiment. Include a diagram of your experimental setup. Label the equipment in your diagram. Also include a description of the measurements you would make and a symbol for each measurement.




- *Use the electronic balance to measure the mass of the objects, $m_o$ .*
- *Hold one object at a height above the ground and measure that height, $h_i$ .*
- *Drop the object such that it has zero initial velocity, $v_i = 0$.*
- *Measure the time it takes for the object to fall to the ground, $\Delta t$.*
- *Repeat 9 more times with different objects at different heights.*

(c) Give a detailed account of the calculations of gravitational potential energy and translational kinetic energy both before and after the transformation, in terms of the quantities measured in part (b).

- *The horizontal zero line is at the ground.*
- *Gravitational Potential Energy initial:* $$PE_{gi} = m_o g h_i$$
- *Gravitational Potential Energy final:* $$PE_{gf} = m_o g h_f = m_o g\left(0\right) = 0$$
- *Kinetic Energy initial:* $$KE_i = \frac{1}{2} m_o v_i^{\,2} = \frac{1}{2} m_o \left(0\right)^2 = 0$$
- *To determine Kinetic Energy final, we need the final velocity of the object. We know the object is in free fall on planet earth and therefore has an acceleration in the y-direction of -g. Use the Uniformly Acceleration Motion equation* $$v_f = v_i + a_y \Delta t = 0 + \left(-g\right)\Delta t = -g\Delta t$$
- *Kinetic Energy final:* $$KE_f = \frac{1}{2} m_o v_f^{\,2} = \frac{1}{2} m_o \left(-g\Delta t\right)^2 = \frac{1}{2} m_o g^2 \Delta t^2$$

(d) After your first trial, your calculations show that the energy increased during the experiment. Assuming you made no mathematical errors, give a reasonable explanation for this result.

*It is difficult to drop anything without accidentally giving it an initial velocity. Perhaps you pushed the object down a bit, this would increase the final velocity and therefore the final kinetic energy of our calculations.*

(e) On all other trials, your calculations show that the energy decreased during the experiment. Assuming you made no mathematical errors, give a reasonable physical explanation for the fact that the average energy you determined decreased. Include references to conservative and nonconservative forces, as appropriate.

*Nonconservative forces such as air friction likely converted some of the mechanical energy to heat and sound, and therefore decreased the kinetic energy measured right before the object hit the ground.*