Workshop Tutorials for Introductory Physics

Solutions to MI7: **Conservation of Energy**

A. Review of Basic Ideas:

Energy

Energy is defined in physics as the ability to do work. This is sensible, because the more **energy** you have, the more work you can do, so we hope you've had a good breakfast!

In physics there are fundamental laws called **conservation** laws, which state that a certain physical quantity is conserved. Examples are conservation of energy and conservation of mass. Energy can change forms, or be **transformed**, but the **total energy** is always conserved.

Two forms of energy we will be looking at are kinetic energy and potential energy. Kinetic energy is energy associated with **motion**, an object of mass m moving at velocity v, has kinetic energy $\frac{1}{2} mv^2$. The units of energy are *joules* (J).

Potential energy comes in several forms, for example gravitational potential energy. The **gravitational** potential energy of an object of mass m at a height h is defined as mgh, where g is the acceleration due to gravity. There are other forms of potential energy also, such as elastic potential energy in a compressed spring and chemical potential energy in food.

Kinetic and potential energy can also be transformed into other forms of energy, such as heat and sound and light, but the total amount of energy is still always **conserved**.

During the day you transform the chemical potential energy of your breakfast into other forms, such as **kinetic energy** when you move, and gravitational **potential energy** when you climb up stairs.

Discussion questions

1. The "other" energy in the bar graph above might be thermal energy (heat) or sound.

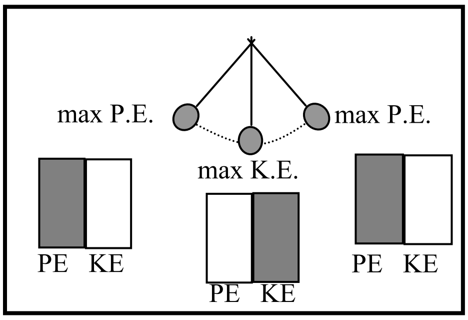
2. Ignoring friction, the velocity at the bottom of a slide depends only on the final and initial heights as potential energy is converted to kinetic energy.

B. Activity Questions:

1 Pendulum

At the lowest point of the pendulum bob's motion, its kinetic energy is maximum and potential energy is minimum.

At the highest point of its motion, kinetic energy is minimum (i.e. zero) and potential energy is maximum.

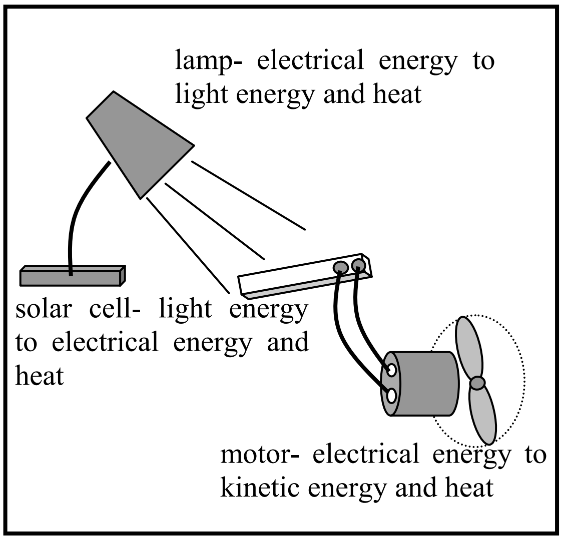


2. Solar panels and electric circuit

Energy as light is converted to electrical energy by the solar cell which is then converted to kinetic energy by the motor. Some energy is also converted to heat, which is usually not considered useful.

Heat is useful energy when you want to heat or cook something.

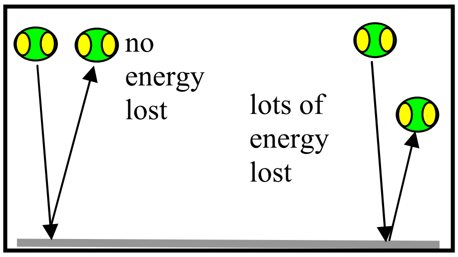
Dammed water has gravitational potential energy, which is converted to kinetic energy when the dam is open. This is converted to kinetic energy of a turbine placed in the flow, which is attached to a generator. The generator turns the kinetic energy into electrical energy which is converted into light, heat, sound or mechanical energy by a home appliance.



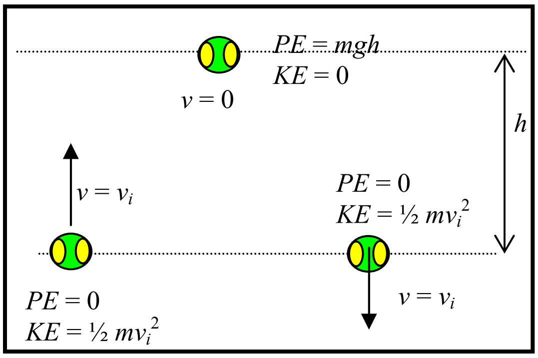
3. Bouncing balls I

a. Balls that lose less energy to non-mechanical forms rise higher than balls that lose more energy.

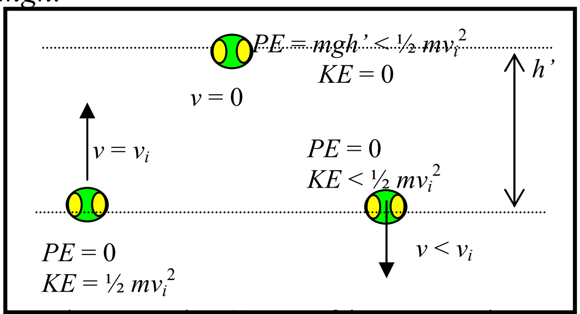
b. A ball can bounce higher than the original height if we throw the balls instead of just dropping them. These balls start off with kinetic energy and gravitational potential energy instead of just gravitational potential energy.



C. Qualitative Questions:



1. a. and b. With no air resistance:
The ball has an initial velocity, v_i, and kinetic energy $KE_i = ½ mv_i^2$. It also has an initial height $h_i = 0$ and potential energy $PE_i = mgh_i = 0$. As the ball goes up, its kinetic energy decreases and is zero at a height of h, its gravitational potential energy increases and is maximum at h. The reverse happens on the way down, such that the total energy of the ball is constant, i.e. at every instant $PE + KE$ = total energy.
Or, in terms of work rather than potential energy, there is no change in kinetic energy of the ball between the initial and final positions thus the total work is zero. During the flight the work done by weight on the way up is $W=-mgh$ and on the way down is $W = mgh$.



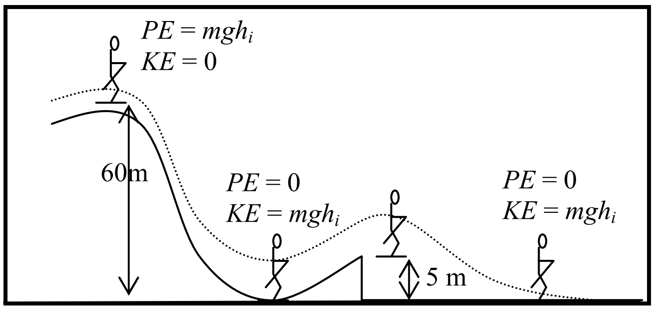
a. and b. With air resistance:
As the ball goes up, there is work done by air resistance, so the ball's kinetic energy decreases and is zero at a height h' which is less than h. On the way down again there is work done by air resistance. Consequently the final kinetic energy is less than the initial kinetic energy, i.e. final speed is less than initial speed. The total energy of the ball-earth system is $PE + KE + W_{\text{air resistance}}$.
Total energy is constant but the ball has less mechanical energy when caught. Some of its energy has been converted into heat due to work done by air resistance.

c. The energy is converted into heat, sound and motion of the muscles in your hand..

d. Your hand must do work on the ball to change its kinetic energy from ½ mv^2 to 0. The work done is given by the force times the distance, so if you increase the distance over which your hand applies the force to stop the ball, the force required is less. If the force on the ball by your hand is less then the force by the ball on your hand will also be less.

2. One possible scenario is someone sliding down a hill with potential energy being converted to kinetic energy and heat due to friction, and hitting a tree at the bottom, the collision converting the kinetic energy into heat and sound. There is a virtually infinite number of possible scenarios!

D. Quantitative Question:



a. PE = mgh_i = 60 kg × 9.8 m.s^{-2} × 60 m = 3.5 ×10^4 J.

b. With no work done against friction, total mechanical energy remains constant, final energy = initial energy

$$\frac{1}{2}mv_f^2 + 0 = 0 + mgh_i = 3.5\times10^4\,\text{J}$$

Hence $v_f = \sqrt{\dfrac{2(3.5\times10^4\,\text{J})}{60\text{ kg}}} = 34\,\text{m.s}^{-1}$

c. Again 34 m.s^{-1} because mechanical energy is conserved.

d. She reaches the bottom of the run, with v = 25m.s^{-1}, which gives $KE = ½ mv^2 = 1.9 \times 10^4$ J.
Thus the energy lost via friction is 3.5 ×10^4 J (KE_i) - 1.9 × 10^4 J (KE_f) = 1.6 × 10^4 J.