sk8art

Grade Level:
high school

Subject Matter:
physics, physical science

Curricular Uses:
This lesson plan enables students to study energy conservation, work, and center of mass

Materials/Resources Required:
- paper, pencil, calculator

Lesson 11 – Perpetual Motion

Overview:

Tony Hawk seems to defy the conservation of energy as he keeps reaching new heights on each pass on the half-pipe. Actually, Tony is supplying the extra energy through work by his muscles and using a pumping action to help him increase his speed and height.

Learning Objectives:

- students will look at energy conservation, work, and center of mass through a connection to skateboarding
- students will calculate gravitational potential energy, kinetic energy and velocity through related problems

Procedures:

Discussion: "A person on a swing is able to rock back and forth and increase their height. Without this action, the person's ride would lack a good deal of the excitement and pleasure. Analysis of the movement of the swing (and of Tony Hawk on the half pipe) should begin with the simplest situation – no pumping.

A pendulum swings back and forth and eventually comes to rest. A bowling ball on the half pipe rolls back and forth and also will eventually come to rest. If we could imagine either of these situations with less and less friction, the movement would continue for a much longer time. Eliminate friction all together (ahh, if it were only possible) and the pendulum and bowling ball would repeat their motion forever.

We describe the motion of both the pendulum and bowling ball in terms of their energy. The total energy must remain the same. As the ball reaches its lowest point, it increases its speed until all of the energy is kinetic energy. As the ball reaches its highest point, it comes to rest and all of the energy is gravitational potential energy. We can us equations to quantify the energy.

Gravitational potential energy=GPE=mgh
Kinetic energy=KE-1/2mv2 where m is the mass, g is the acceleration due to gravity, h is the height above the lowest point of travel, and v is the velocity.

Since the total energy must remain the same, the kinetic energy at the bottom must equal the gravitational potential energy at the top. At every other point, the sum of the kinetic energy plus the gravitational potential energy, must be constant and must equal the gravitational potential energy at the top. If we use subscripts to denote position 1 and position 2 of the motion, we can state: $KE_1 + GPE_1^{\circ} = KE_2 + GPE_2^{\circ}$

To increase our maximum height, we lower our bodies at the bottom of the arc. Tony does this by bending his knees; we do this by leaning back at the bottom of the swing's arc. Thie effectively lowers our GPE at the bottom an extra bit and provides us with a bit more kinetic energy, KE. As we get to the top of the arc, we sit up straight or stand up giving us another increase in GPE. This effectively gives us a larger drop and some extra kinetic energy which will help us get even higher on the next oscillation.

The kinetic energy of the person increases with each back and forth swing. The extra kinetic energy comes from the work that the person does in lifting himself or herself on each turn. Work has a very specific

meaning in physics. It can be defined and measured. The equation for work is W=f Æ where f is the applied force and d is the displacement. When lifting your body, you must exert a force equal to your weight. If you weigh 700 Newtons (equivalent to 160 pounds) and you lift your body 0.8 meters, then you have done (700N)(0.8m)=560 Joules of work. You can expect to see an increase of your kinetic energy at the bottom of the hill of 560 Joules.

You can keep this up as long as your muscles don't tire. The energy comes from muscles that are strengthened by exercise and nourished by changes in chemical energy from the foods we eat.

Activities:

1. A skateboarder is riding the half-pipe. Assuming that his mass is 60 kilograms and the height of the half-pipe is 3 meters. Calculate the (a) gravitational potential energy at the top, (b) the kinetic energy at the bottom, and (c) the velocity at the bottom.
2. A child on a swing is able to lift her 500 N body by 0.4 meters as the swing gets to the top of its swing. Please calculate (a) the work done by the child, (b) the increase in gravitational potential energy at the top of the swing and (c) the increase in kinetic energy at the bottom of the swing.
3. A high school student consumes 3000 Calories a day. Each food Calorie (upper case C) is really 1000 calories (lower case c). Each calorie is equivalent to 4.2 Joules of energy.
    a. Calculate the energy consumption of the student in Joules.
    b. Shovelling snow requires approximately 50 Joules per shovel. How much snow could you shovel with this much energy?
    c. Clearly, all of your consumed energy from food is not going to work output (shovelling snow.) Where do you suspect most of your food energy is used?

Evaluation:

Credit:

- http://sportsfigures.espn.com/sportsfigures/lp_perpetual_motion.jsp

Extended Activity:

1. Use a washer connected to a string to demonstrate how you can increase the height by lowering the string a bit as the swinging washer is at the bottom and raising the string a bit as the swinging washer is at the top.