Conservation of Energy

Physics 112

Work

- In physics, work is done on an object when a force causes a displacement of the object.

- The formula is: $W = Fd$

- F is the force acting parallel to the direction of motion.

- d is the displacement, not the total distance.

- W is the work done, it has the unit of energy called Joules, J.
  - 1 J of work is lifting an apple to the top of your head.

Positive and Negative Work

- Work is a scalar quantity, meaning it is independent of the coordinate system.
- However, it can be negative or positive. Its sign depends on the direction of the displacement.
- When the force and displacement are in the same direction, work is positive.
- When the force and the displacement are in the opposite direction, work is negative.
  - Applying the breaks to a car is an example of negative work.
  - Work done by kinetic friction is always negative.

Kinetic Energy, E_k

- The energy associated with an object in motion.
- $E_k = \frac{1}{2}mv^2$
- *m* is the mass in kilograms and *v* is the object's speed in m/s. The units of kinetic energy is Joules.

Gravitational Potential Energy, E_g

- Potential energy is stored energy. The object has the *potential* to move.
  - Associated with an object because of the position, shape, or condition of the object.
- Gravitational potential energy depends on the height from a zero level.
  - The stored energy of an object due to its position relative to a gravitational source.
- **E_g = *mgh***
- ***m*** is the mass in kg, ***g*** the acceleration due to gravity (9.81 m/s^2) and ***h*** is the height ***above a zero level***.
- E_g is energy, so it is measured in Joules.

Elastic Potential Energy, E_e

- Energy stored that depends on the distance an object has been compressed or stretched.
    - $E_e = \frac{1}{2}kx^2$
    - x = stretch length or amount of compression, measured in meters.
    - k = spring constant, measured in N/m.
- The spring constant is a measure of the resistance to being compressed or stretched.
    - Flexible strings have low k-values, stiff springs have high k-values.
- Elastic materials always try to get back to their natural, or neutral, positions. They apply a *restoring force*, called Hooke's Law.
    - $F_s = -kx$, negative because it acts opposite to the compression or stretch.

Conservative and Nonconservative Forces

- **Conservative Force**: Does work on an object in such a way that the amount of work done is independent of the path taken.
  - Energy changes are reversible.
- **Nonconservative Force**: The work done is path-dependent.
  - Kinetic friction is such a force.
  - May not be reversible.

Energy Transformations

- Energy can be changed, or converted, from one type to another.
  - Dropping a book changes gravitational potential energy into kinetic.
  - Compressing a spring to shoot a toy gun changes E_e to E_k.
- Law of Conservation of Energy:
  - Energy can neither be created nor destroyed, but it can be transformed from one form to another or transferred from one object to another. The total energy of an isolated system, including all forms of energy, always remains constant.

Applying Conservation of Total Energy

- If all the forces in a problem are conservative (i.e. no friction, air resistance, etc.) then the change in total mechanical energy, from all sources, is zero.
  - $\Delta E_T = 0 \rightarrow \Delta E_k + \Delta E_g + \Delta E_e = 0$
- If there exists nonconservative forces, then the change in total mechanical energy is equal to the work done by the nonconservative force. W_{nc} will be negative since mechanical energy is removed from the system.
 - $\Delta E_T = W_{nc}$

Conservation of Energy: Conservative Forces

- A roller coaster at a popular amusement park has a section as shown in the image. Assuming no friction, calculate the velocity at the top of the loop.

$V_1 = 0$

70 m

$V_2 = ?$

30 m
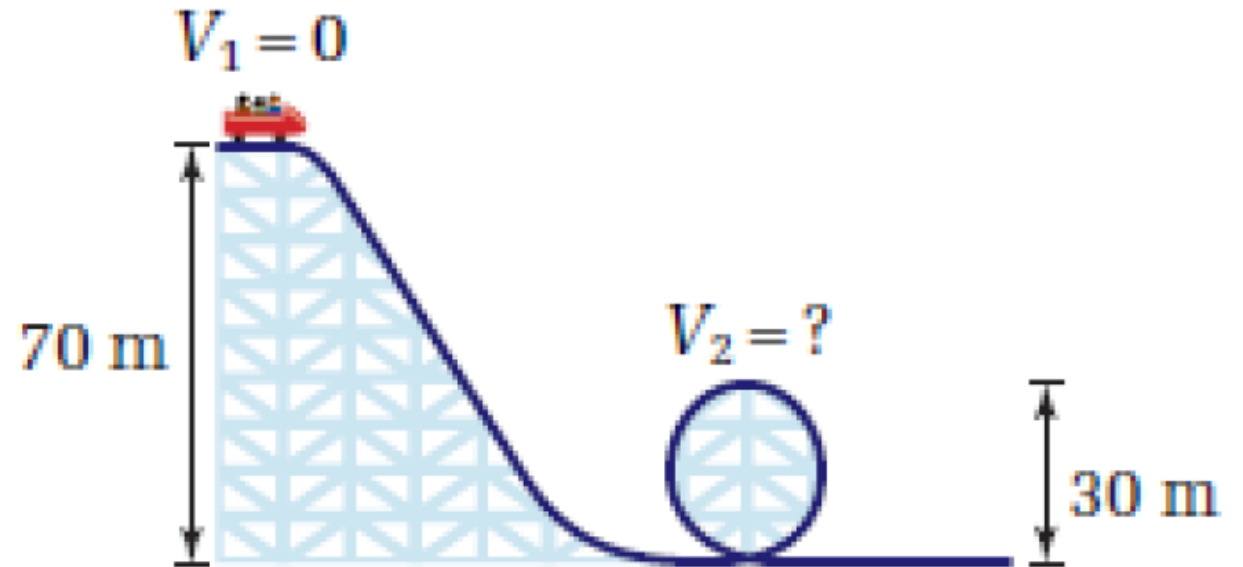
Conservation of Energy: Conservative Forces

- A 5.0 kg mass is dropped from a height of 3.5 meters. The mass lands on a large spring and compresses it 0.72 m to stop the mass. Calculate the spring constant, k.

m

h_o
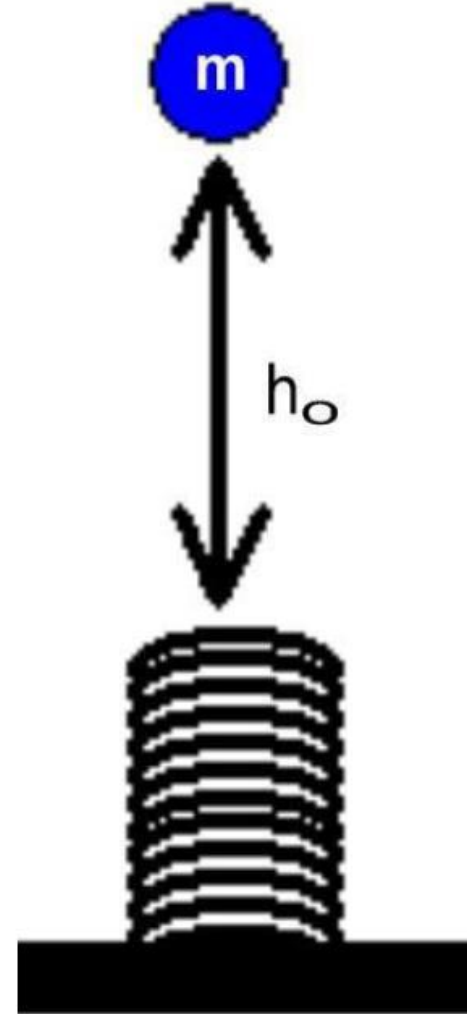
Conservation of Energy: Nonconservative Forces