The Binary Star Experiment

Physics 109, Class Period 8
This is Experiment Number 5
In the Physics 121 Lab Manual

Outline
• Description of the Experiment
• The different parts of the experiment
  – Hooke’s Law, or the spring constant
    • Chapter 5, page 113
  – Energy of the spring, Chapter 8, p. 193
  – Energy of two interacting objects
    • Conservation of energy
      – Chapter 8, pp 202-203
  – Momentum of a system
    • Conservation of momentum
      – Chapter 10, pp 247-249
• Questions based on homework.
• Questions based on the concepts covered today.

Description of the Experiment
• Study the conservation of energy and momentum in a binary star system.
• We simulate the system using two pucks of equal mass allowed to move on a horizontal air table (to minimize friction)
• The pucks are connected by a spring which approximates the gravitational interaction and allows orbital motion.

What is a Binary Star?

Simulation

Albireo
Hooke’s Law

- Force, \( F = -k (r-r_0) \) (the spring constant)(\( r-r_0 \))(the distance of tension or compression of the spring.) The – sign indicates that the force is directed opposite to the tension or compression of the spring.
- The ENERGY stored in a spring is equal to \( \frac{1}{2} \) the force times the distance, or \( V(r) = \frac{1}{2} k (r-r_0)^2 \)
  - Note that the sign now does not matter since the distance term is squared
  - Also note that the gravitational interaction would give an energy \( V = -\frac{Gm_1 m_2}{r} \)
- This is POTENTIAL ENERGY, a quantity defined in Chapter 8, p 190.

Energy of Two Interacting Objects

- The total energy is: \( E_{\text{total}} = K_1 + K_2 + V(r) \) where \( K \) refers to the kinetic energy of each object, and \( V \) is the potential energy of the interaction.
- The kinetic energy, \( K = \frac{1}{2} mv^2 \)
- The total energy is: \( E_{\text{total}} = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 + \frac{1}{2} k (r-r_0)^2 \)
- Or: \( (2/m) E_{\text{total}} = v_1^2 + v_2^2 + \frac{(k/m)}{2} (r-r_0)^2 = \) a constant, since energy is conserved.
Momentum of the System

- Conservation of momentum means that if no outside influences are acting on the system, then the momentum of its center of mass will not change.

- So, $p_{\text{total}} = m_{\text{total}}v_{\text{cm}}$, where boldface means a vector, and $v_{\text{cm}}$ is the velocity of the center of mass. This shows that the center of mass moves at a constant speed and in a constant direction.

One Additional Concept—Conservative Forces

- A conservative force is one for which its action over a closed path leads to a total work of zero.

- A conservative force is also one for which the amount of work done from A to B is independent of the path taken
  – Example—gravitational force.

Problems

- Problems based on Homework
- Conservation of Energy
  – Potential energy
  – Kinetic Energy
- Conservation of Momentum
- Hooke’s Law

What is the difference in potential energy for a mass $m$ between the valley and the mountain top?

- A. $mg(1900-86)$  B. $mg(86)$  C. $mg(1900+86)$  D. $mg(1900)$
Which of the following brick orientations has the highest potential energy?

A  B  C  D

Which equation gives the energy stored in the stretched spring?

• A. \( E = kx \)
• B. \( E = \frac{1}{2} kx^2 \text{ Corr.} \)
• C. \( E = 2 kx \)
• D. \( E = 2 kx^2 \)

What equation gives the height of the arrow?

• A. \( h = k(0.71)/mg \)
• B. \( h = k(0.71)^2/2mg \text{ Corr.} \)
• C. \( h = mg/ k(0.71)^2 \)
• D. \( h = k(0.71)/2mg \)

Which equation do we use to find \( X_1 \), given \( M_1 \), \( M_2 \) and \( X_2 \)?

• A. \( M_1X_2 = M_2X_1 \)
• B. \( M_1X_1 = M_2X_2 \text{ Corr.} \)
• C. \( X_1 = M_1X_2/M_2 \)
• D. \( X_2 = M_2X_1/M_1 \)
Where is the most likely center of gravity of the water molecule?

- C. is correct

Summary

- The concepts of momentum, potential and kinetic energy, and their conservation have been introduced.
- Assignment—read the material covering these topics-see assignment web page.