PHYS 1441 – Section 002
Lecture #15

Wednesday, Apr. 1, 2009

Dr. Jaehoon Yu

- Elastic Potential Energy
- Conservation of Energy
- Power

Announcements

- Quiz Monday, Apr. 6
  - At the beginning of the class
  - Covers CH6.1 – 6.10
- Colloquium today
  - At 4pm in SH101
- Mid-term grade discussion today
  - In my office, CPB342
  - Start with those who has a class immediately after this one

Physics Department
The University of Texas at Arlington
COLLOQUIUM

A Fundamental Physical Problem in 21cm Cosmology

Dr. Li-Zhi Fang
University of Arizona

Wednesday, April 1, 2009 at 4:00 pm in Room 101 SH

Abstract

Detecting the emission or absorption of redshifted 21 cm hyperfine line of neutral hydrogen with large low-frequency radio arrays is generally viewed as a frontier in observational cosmology of the coming decades. The 21 signals come from the first generation of stars formed at the end of dark age of the universe. It would be the most promising probe of the epoch of reionization. To estimate the 21 signal from early universe, we need to study a fundamental physical problem: how a system of photons and atoms approaches to statistical equilibrium when the resonant scattering between photon and atom is considered. This problem has been addressed on as early as 1950s (Wouthuysen 1952, Field 1958). However, the quantitative solutions of the Wouthuysen-Field (W-F) coupling, which is necessary for 21 cm cosmology, are obtained very recently. I will present the story of 21 cm cosmology and the time evolution of the W-F coupling.

Refreshments will be served in the Physics Lounge at 3:30 pm

Special Project

1. A ball of mass M at rest is dropped from the height h above the ground onto a spring on the ground, whose spring constant is k. Neglecting air resistance and assuming that the spring is in its equilibrium, express, in terms of the quantities given in this problem and the gravitational acceleration g, the distance x of which the spring is pressed down when the ball completely loses its energy. (10 points)
2. Find the x above if the ball's initial speed is v_i. (10 points)
3. Due for the project is Wednesday, April 8.
4. You must show the detail of your work in order to obtain any credit.

Elastic Potential Energy

Potential energy given to an object by a spring or an object with elasticity in the system that consists of an object and the spring.

The force spring exerts on an object when it is distorted from its equilibrium by a distance x is

$$F_s = -kx$$

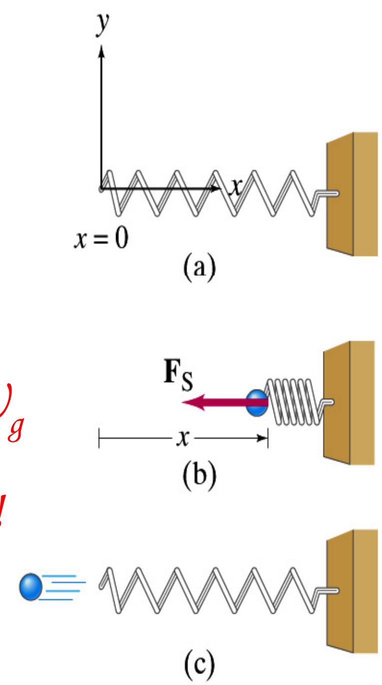
Hooke's Law

The work performed on the object by the spring is

$$W_s = \int_{x_i}^{x_f} (-kx)\,dx = \left[-\frac{1}{2}kx^2\right]_{x_i}^{x_f} = -\frac{1}{2}kx_f^2 + \frac{1}{2}kx_i^2 = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$$

The potential energy of this system is

$$U_s \equiv \frac{1}{2}kx^2$$



What do you see from the above equations?

The work done on the object by the spring depends only on the initial and final position of the distorted spring.

Where else did you see this trend?

The gravitational potential energy, U_g

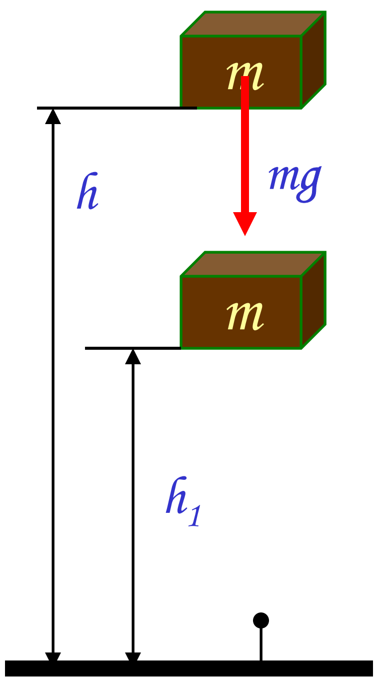
So what does this tell you about the elastic force?

A conservative force!!!

Conservation of Mechanical Energy

Total mechanical energy is the sum of kinetic and potential energies

$$E \equiv K + U$$



Let's consider a brick of mass *m* at the height *h* from the ground

What is the brick's potential energy?

$$U_g = mgh$$

What happens to the energy as the brick falls to the ground?

$$\Delta U = U_f - U_i = -\int_{x_i}^{x_f} F_x dx$$

The brick gains speed *By how much?*

$$v = gt$$

So what? *The brick's kinetic energy increased*

$$K = \frac{1}{2}mv^2 = \frac{1}{2}mg^2t^2$$

And? *The lost potential energy is converted to kinetic energy!!*

What does this mean?

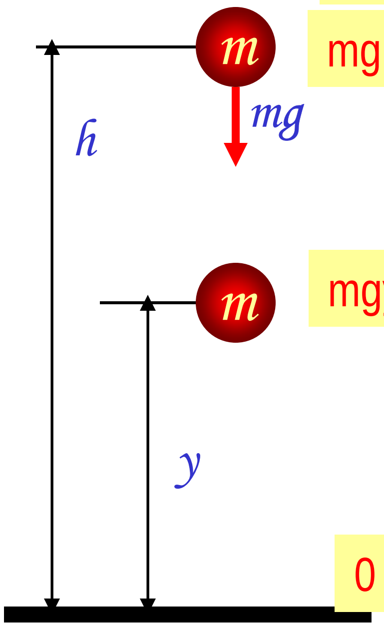
The total mechanical energy of a system remains constant in any isolated system of objects that interacts only through conservative forces: ***Principle of mechanical energy conservation***

$$E_i = E_f$$

$$K_i + \sum U_i = K_f + \sum U_f$$

Example

A ball of mass m at rest is dropped from the height h above the ground. a) Neglecting air resistance, determine the speed of the ball when it is at the height y above the ground.



PE	KE	
mgh	0	$mv_i^2/2$
mgy	$mv^2/2$	$mv_f^2/2$
0		

Using the principle of mechanical energy conservation

$$K_i + U_i = K_f + U_f \quad 0 + mgh = \frac{1}{2}mv^2 + mgy$$

$$\frac{1}{2}mv^2 = mg(h-y)$$

$$\therefore v = \sqrt{2g(h-y)}$$

b) Determine the speed of the ball at y if it had initial speed v_i at the time of the release at the original height h.

Again using the principle of mechanical energy conservation but with non-zero initial kinetic energy!!!

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}mv_i^2 + mgh = \frac{1}{2}mv_f^2 + mgy$$

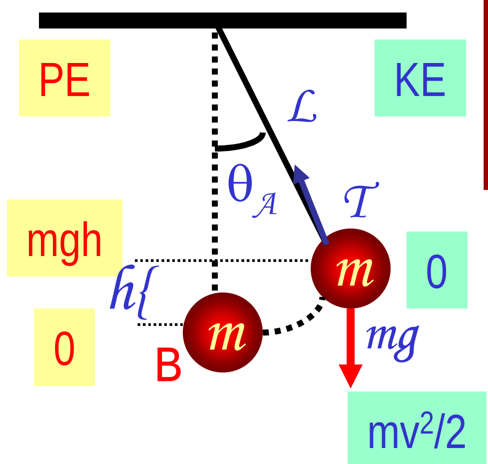
$$\frac{1}{2}m\left(v_f^2 - v_i^2\right) = mg(h-y)$$

$$\therefore v_f = \sqrt{v_i^2 + 2g(h-y)}$$

This result look very similar to a kinematic expression, doesn't it? Which one is it?

Example

A ball of mass m is attached to a light cord of length L, making up a pendulum. The ball is released from rest when the cord makes an angle θ_A with the vertical, and the pivoting point P is frictionless. Find the speed of the ball when it is at the lowest point, B.



Compute the potential energy at the maximum height, h. Remember where the 0 is.

$$h = L - L\cos\theta_A = L(1-\cos\theta_A)$$

$$U_i = mgh = mgL(1-\cos\theta_A)$$

Using the principle of mechanical energy conservation

$$\boxed{K_i + U_i = K_f + U_f}$$

$$0 + mgh = mgL(1-\cos\theta_A) = \frac{1}{2}mv^2$$

$$v^2 = 2gL(1-\cos\theta_A) \qquad \boxed{\therefore v = \sqrt{2gL(1-\cos\theta_A)}}$$

b) Determine tension T at the point B.

Using Newton's 2nd law of motion and recalling the centripetal acceleration of a circular motion

$$\sum F_r = T - mg = ma_r = m\frac{v^2}{r} = m\frac{v^2}{L}$$

$$T = mg + m\frac{v^2}{L} = m\left(g + \frac{v^2}{L}\right) = m\left(g + \frac{2gL(1-\cos\theta_A)}{L}\right)$$

$$= m\frac{gL + 2gL(1-\cos\theta_A)}{L}$$

$$\boxed{\therefore T = mg(3-2\cos\theta_A)}$$

Cross check the result in a simple situation. What happens when the initial angle θ_A is 0? $T = mg$