PHY131H1S - Class 15

- Today:
- Stable and Unstable Equilibrium
- Hooke's Law
- Elastic Potential Energy
- Energy in Collisions
- Elastic, Inelastic Collisions

Ch.10 Reading Quiz 1:

- Two objects collide. All external forces on the objects are negligible.
- If the collision is "perfectly elastic", that means it conserves

A. Momentum $p=mv$
B. Kinetic energy $E = ½ mv^2$
C. Both
D. Neither

Ch.10 Reading Quiz 2:

- Two objects collide. All external forces on the objects are negligible.
- If the collision is "inelastic", that means it conserves

A. Momentum $p=mv$
B. Kinetic energy $E = ½ mv^2$
C. Both
D. Neither

- All collisions conserve momentum.
- Energy can sometimes be lost if the objects that collide are deformed or create heat in some way.

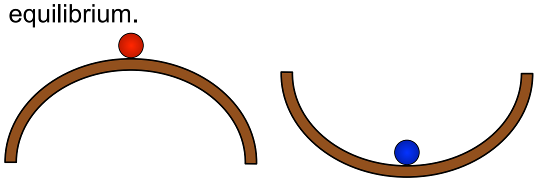
Ch.10 Reading Quiz 3:

- Two objects collide. All external forces on the objects are negligible.
- If the collision is "perfectly inelastic", that means

A. momentum is not conserved.
B. the final kinetic energy is zero.
C. the objects stick together.
D. one of the objects ends with zero velocity.

Last day I asked at the end of class:

- A red marble is balanced on the top of a smooth hill. A blue marble sits at the bottom of a smooth valley. Which marble is in equilibrium?
- ANSWER: They both are!
- What is the difference between these two situations?
- ANSWER: The red marble is in *unstable* equilibrium. The blue marble is in *stable* equilibrium.



Dominoes

- A domino is a rectangular solid which can be balanced on its edge
- When standing upright, its gravitational potential energy is a maximum

- This is a state of **unstable equilibrium**: a small perturbation can cause the domino to fall, transforming its gravitational potential energy into kinetic energy
- As it is falling, it can perturb its neighbor, which then releases its potential energy: a ***chain reaction*** can ensue!

Hooke's Law

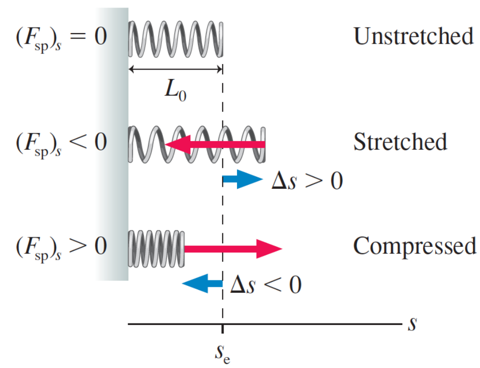
- If you stretch a rubber band, bend a ruler or other solid object, a force appears that tries to pull the object back to its equilibrium, or unstretched, state.
- A force that restores a system to an equilibrium position is called a **restoring force**.
- If s is the position, and s_e is the equilibrium position, we define $\Delta s = s - s_e$.

$$(F_{sp})_s = -k\,\Delta s \qquad \text{(Hooke's law)}$$

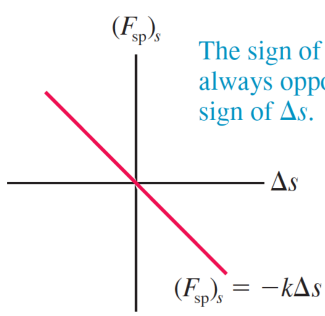
where $(F_{sp})_s$ is the s-component of the restoring force, and k is the spring constant of the spring.

- The minus sign reminds you that it is a *restoring force*.

Hooke's Law

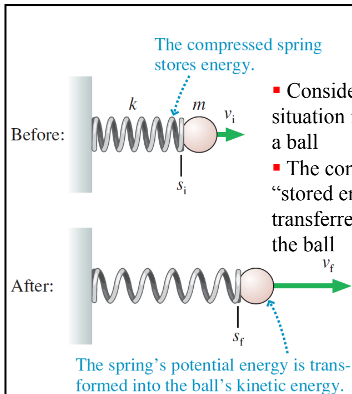


Hooke's Law



The sign of $(F_{sp})_s$ is always opposite the sign of Δs.

Elastic Potential Energy



- Consider a before-and-after situation in which a spring launches a ball
- The compressed spring has "stored energy," which is then transferred to the kinetic energy of the ball
- We define the **elastic potential energy** U_s of a spring to be:

$$U_s = \frac{1}{2}k(\Delta s)^2$$

A spring-loaded gun shoots a plastic ball with a speed of 4 m/s. If the spring is compressed twice as far, the ball's speed will be

A. 1 m/s.
B. 2 m/s.
C. 4 m/s.
D. 8 m/s.
E. 16 m/s.

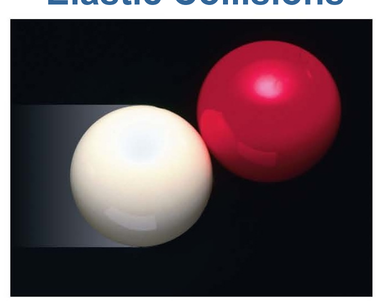
$$E_f = E_i$$

$$\frac{1}{2}mv_f^2 + \frac{1}{2}kx_f^2 = \frac{1}{2}mv_i^2 + \frac{1}{2}kx_i^2$$

$$\frac{1}{2}mv_f^2 + 0 = 0 + \frac{1}{2}kx_i^2$$

$$v_f = \sqrt{\frac{k}{m}}x_i$$

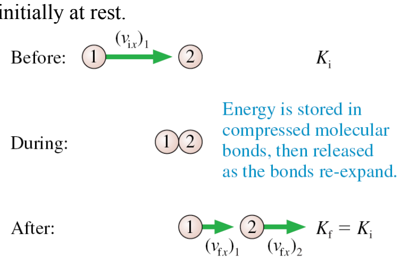
Elastic Collisions



A perfectly elastic collision conserves both momentum and mechanical energy.

1D Elastic Collision when ball 2 is initially at rest.

Consider a head-on, perfectly elastic collision of a ball of mass m_1 having initial velocity $(v_{ix})_1$, with a ball of mass m_2 that is initially at rest.



The balls' velocities after the collision are $(v_{fx})_1$ and $(v_{fx})_2$.

1D Elastic Collision when ball 2 is initially at rest.

momentum conservation: $m_1(v_{fx})_1 + m_2(v_{fx})_2 = m_1(v_{ix})_1$

energy conservation: $\frac{1}{2}m_1(v_{fx})_1^2 + \frac{1}{2}m_2(v_{fx})_2^2 = \frac{1}{2}m_1(v_{ix})_1^2$

There are two equations, and two unknowns: v_{fx1} and v_{fx2}. You can solve this. The solution is:

Eq. 10.43:

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1$$

$$(v_{fx})_2 = \frac{2m_1}{m_1 + m_2}(v_{ix})_1$$

(perfectly elastic collision with ball 2 initially at rest)

Elastic Collision when ball 2 is initially at rest.

Eq. 10.43:

$$(v_{fx})_1 = \frac{m_1 - m_2}{m_1 + m_2}(v_{ix})_1$$

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(perfectly elastic collision with ball 2 initially at rest)

These equations come in especially handy, because you can always switch into an inertial reference frame in which ball 2 is initially at rest!

Demonstration and Example

- A 0.50 kg basketball and a 0.05 kg tennis ball are stacked on top of each other, and then dropped from a height of 0.82 m above the floor.
- How high does the tennis ball bounce?
- Assume all perfectly elastic collisions.

Demonstration and Example

- Divide motion into segments.
- Segment 1: free-fall of both balls from a height of h = 0.82 m. Use conservation of energy: $U_f + K_f = U_i + K_i$
- $0 + ½\, m\, v_f^2 = mgh + 0$
- $v_f = [2gh]^{½} = -4.0$ m/s, for both balls.
- Segment 2: basketball bounces elastically, so its new velocity is +4.0 m/s.

Demonstration and Example

- Segment 3: A 0.50 kg basketball moving upward at 4.0 m/s strikes a 0.05 kg tennis ball, initially moving downward at 4.0 m/s.
- Their collision is perfectly elastic.
- What is the speed of each ball immediately after the collision?

Demonstration and Example

- Segment 4: freefall of tennis ball on the way up. vi = +10.5 m/s.
- Use conservation of energy: $U_f + K_f = U_i + K_i$
- $mgh + 0 = 0 + \frac{1}{2} m v_i^2$
- $h = v_i^2/(2g) = 5.6$ m.
- So the balls were dropped from 0.82 m, but the tennis ball rebounds up to 5.6 m! (Assuming no energy losses.)

Before Class 16 next Wednesday

- Note that U of T is closed on Monday and Tuesday for “Fall Reading Break”
- Remember MasteringPhysics.com Problem Set 7 on Chapter 10 is due Friday
- The Pre-Class Quiz on Chapter 11 is due by 10am on ***Wednesday*** of next week
- Something to think about:
- If one object does work on another object, does energy always get transferred from one object to the other?
- Have a great break!!