Physics 1A, Lecture 12: Linear Momentum: Impulse and collisions

Summer Session 1, 2011

The quiz will commence at 9:33 AM.

Key Questions: (Discuss with neighbors before quiz)

1) What is the relationship between potential energy and force?
2) What is the relationship between force and momentum?
3) What is conservation of momentum?
4) What is the formula for linear momentum?
5) What is impulse?

Reading Quiz #10-1

- What is the relationship between potential energy and force?

A. Force is the derivative of potential energy

$$F = -\frac{dU}{dx}$$

B. Force is the integral of potential energy

$$F = -\int U\,dx$$

C. Force has nothing to do with potential energy

Reading Quiz #10-2

- What is the relationship between force and momentum?

A. Force is the derivative of momentum

$$F = \frac{dp}{dt}$$

B. Force is the integral of momentum

$$F = \int p dt$$

C. Force has nothing to do with momentum

Reading Quiz #10-3

- What is conservation of momentum?

A. It is a restatement of Newton's first law.
B. It is a restatement of Newton's second law.
C. It is a restatement of Newton's third law.
D. The total momentum of an object must be constant over time.
E. The total momentum of an isolated system of objects must be constant over time.

Reading Quiz #10-4

- What is the formula for linear momentum?

A) $p = m/v$

B) $p = mv$

C) $p = \frac{1}{2} mv^2$

D) $p = ma$

E) $p = F\ d$

Reading Quiz #10-5

- What is impulse?

A) It is equivalent to the work done on an object

B) It is the tendency of an object in motion to continue its motion

C) It is the derivative of the force over an interval of time

D) It is the amount that the momentum of an object has changed after a force has been exerted on it over an interval of time.

Announcements

- HW #4 is due by 1pm
- Office hours:
  - Me in Mayer 5623 at noon
  - Evan in Mayer 2702 from 2-4pm
  - Tutorial center closing at 4:30
  - Problem session in Peterson 104 from 5-6pm
- Pick up old homework from me

Anonymous poll

- How do you feel about the use of calculus in this class?

A) Good. I think I get it and it's really helping me to see what calculus is used for.
B) I feel a little unsure about it, but I'm guessing that it's for my own good and that it will help me understand topics in future physics classes.
C) I had no idea that this class had a pre-req for calculus and I get really nervous and upset every time you or the book mentions the words integral or derivative.

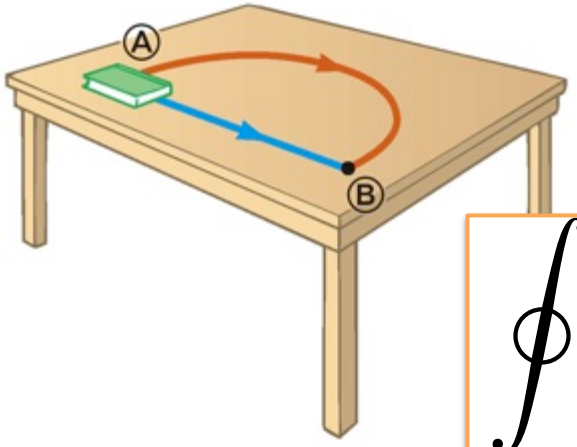
Conservative vs. Non conservative

Conservative Forces

- Work done is independent of the path taken
- Reversible

Non-conservative Forces

- Work done is not independent of the path taken
- Irreversible



$$\oint F_c \cdot dx = 0$$

Work and energy for nonconservative forces

- Modify Work-Energy equations:

$$W_c + W_{nc} = \Delta KE$$

$$W_c = -\Delta PE$$

- Energy conservation only when $W_{nc} = 0$.

$$\Delta E_{tot} = \Delta KE + \Delta PE = W_{nc}$$

$$E_f - E_i = W_{nc}$$

Clicker Question 10-1

- Which of the following is true?

A) W_{nc} is always positive or zero.

B) W_{nc} is always negative or zero.

C) W_{nc} can be positive or negative or zero.

Practice solving problems with energy conservation

- You push a 20 N box horizontally with a constant force of 50 N. The coefficient of kinetic friction with the ground is 0.5. What is the velocity of the box after you have pushed the box 10 m if it starts from rest?

(1) Draw a picture with a coordinate system for *both* the initial and final condition.

(2) Fill out an energy chart, including the energy lost.

(3) Write out work/energy equations and equations for conservation of energy.

(4) Solve algebra.

Practice solving problems with energy conservation

A 100 kg box is at a height of 5 m. It slides down a ramp that is at an incline of 50^o. The coefficient of kinetic friction is 0.50. What is the final velocity of the box when it reaches the bottom of the ramp?

(1) Draw a picture with a coordinate system for *both* the initial and final condition.

(2) Fill out an energy chart, including the energy lost.

(3) Write out work/energy equation.

(4) Solve algebra.

Practice solving problems with energy conservation

- You try to keep a box lifted by pushing it up against a wall but it starts slipping. You continue to push with a constant force of 200 N as it falls. The weight of the box is 300 N. The coefficient of kinetic friction is 0.5. The box starts out 1.5 meters off the ground. What is the velocity with which it hits the ground?

(1) Draw a picture with a coordinate system for *both* the initial and final condition.

(2) Fill out an energy chart.

(3) Write out work/energy equations and equations for conservation of energy.

(4) Solve algebra.

Clicker 10-2

- A mass m compresses a spring with a spring constant k a distance x before it is released to slide across a floor with friction. The coefficient of kinetic friction is μ. What distance d will the mass travel before it comes to a stop?

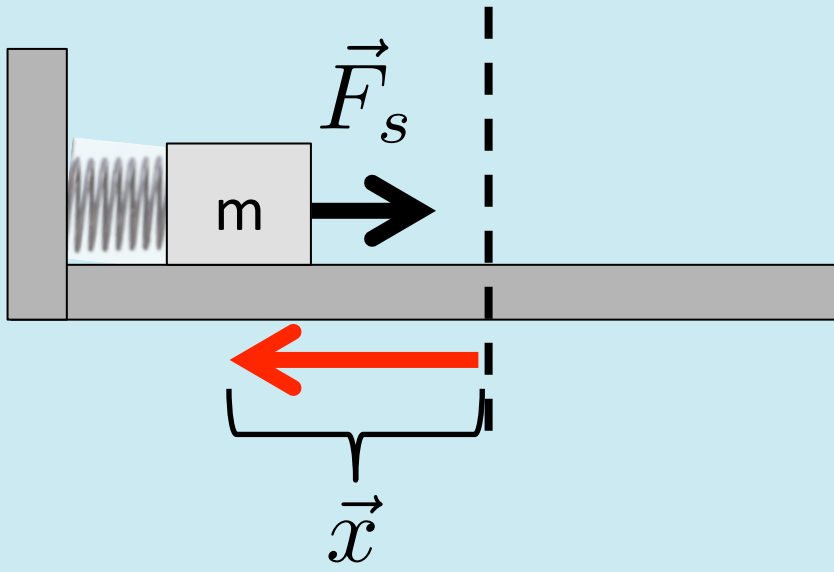
$A)\ \dfrac{kx}{2\mu mg}$

$B)\ \dfrac{kx}{\mu mg}$

$C)\ \dfrac{kx^2}{2\mu mg}$

$D)\ \dfrac{kx^2}{\mu g}$

$E)\ \sqrt{\dfrac{kx}{2\mu mg}}$



Obtaining Force from Potential energy

- Potential energy is related to force by the following:

$$PE = -W = -\int F \cdot dx$$

- But if you want to find force when given potential energy then take the derivative:

$$F = -\frac{d(PE)}{dx}$$

- Ex:

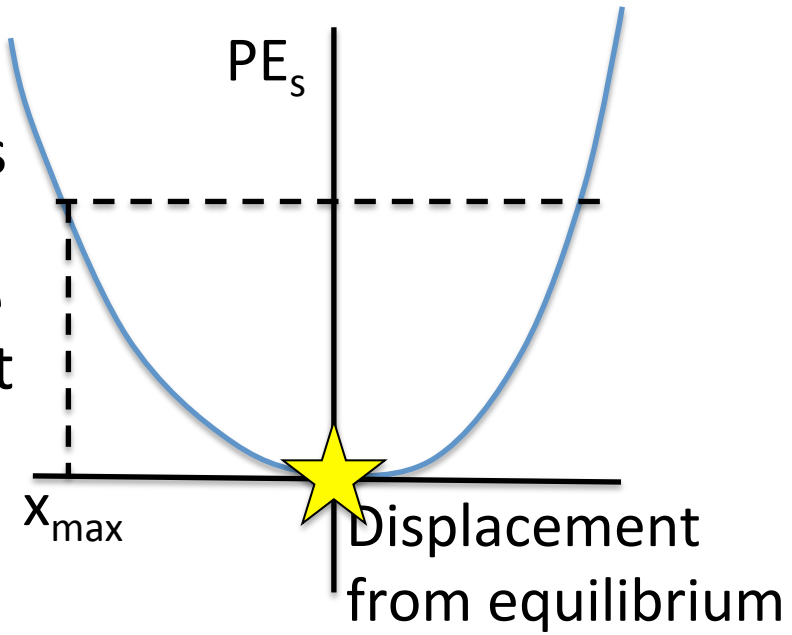
$$PE_s = \frac{1}{2}kx^2 \rightarrow \vec{F}_s = -kx$$

$$PE_g = mgh \rightarrow \vec{F}_g = -mg \cdot \hat{y}$$

Potential Energy curves

- We can study potential energy curves (PE vs x) to understand where force is the strongest.
- For example, let's look at a mass on a spring:
- Where the slope is greatest the force is greatest.
- Where the slope is zero the force is zero.
- So from this potential energy curve we can observe that force is zero at x = 0 and greatest at ±xmax.

$$PE_s = \frac{1}{2}kx^2$$



Potential energy for a field force

$$PE = -\int F \cdot dx$$

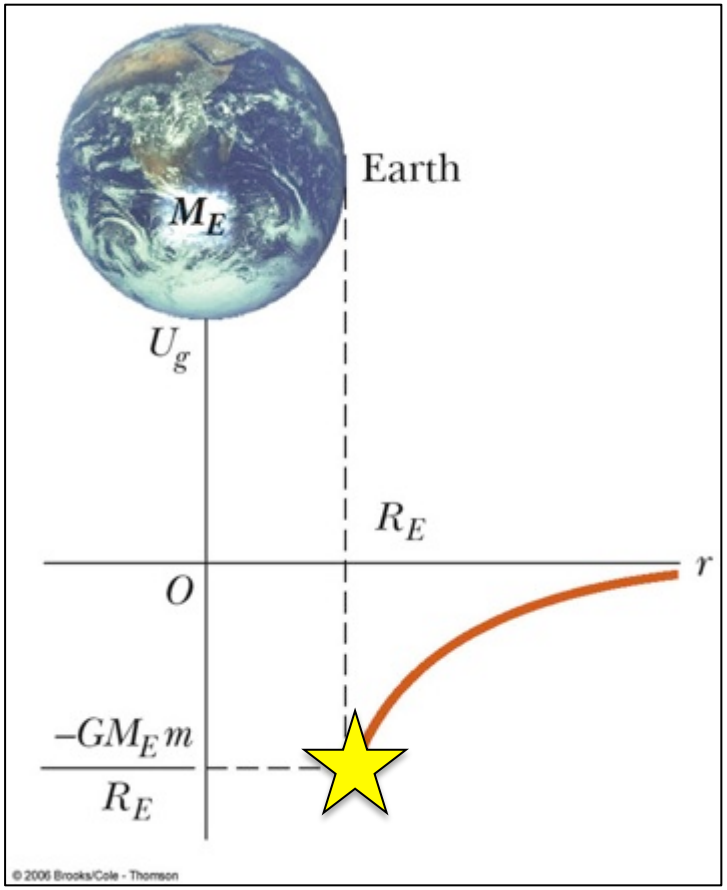
$$F_g = \frac{Gm_1m_2}{r^2}$$

$$PE_g = -\int F_g \cdot dr = -\frac{Gm_1m_2}{r}$$

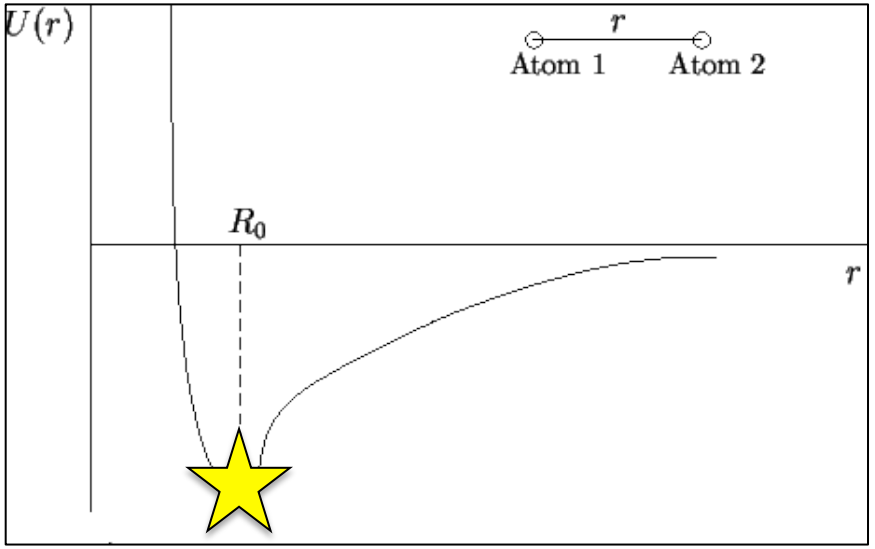
$$PE_g \approx mgh$$

Potential Energy for field forces

$$PE_g = -\frac{Gm_1m_2}{r}$$



Lennard-Jones potential



- Systems eventually settle to the minimum of the potential energy – stable equilibrium point

Example

Suppose the Earth were suddenly to cease revolving around the Sun. The gravitational force would then pull it directly into the Sun. With what speed would the Earth crash into the Sun?

$$PE_g = -\frac{Gm_1m_2}{r}$$

$$E_{tot,i} = KE_i + PE_i$$

$$E_{tot,i} = 0 + (-G\frac{m_S m_E}{R_{ES}})$$

$$E_{tot,f} = \frac{1}{2}m_E v_F^2 + (-G\frac{m_S m_E}{r_E + r_S})$$

$$v_F = 6.14 \times 10^5 \text{ m/s}$$

Homework

- HW #4 is due by 1pm
- Office hours:
  - Me in Mayer 5623 at noon
  - Evan in Mayer 2702 from 2-4pm
  - Problem session in Peterson 104 from 5-6pm
- Pick up old homework from me
- Quiz #3 is tomorrow morning