Physics 131-Physics for Biologists I

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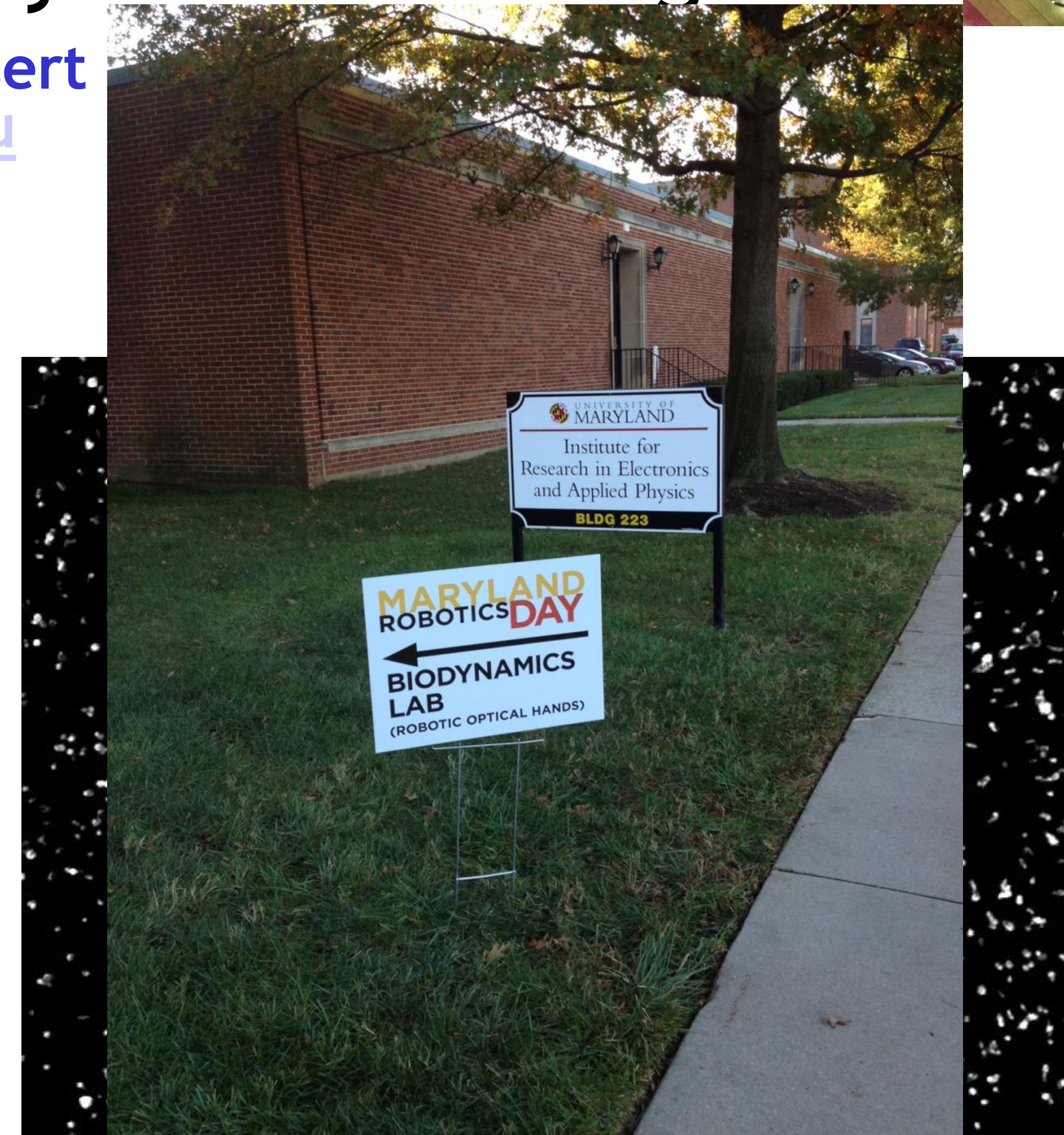
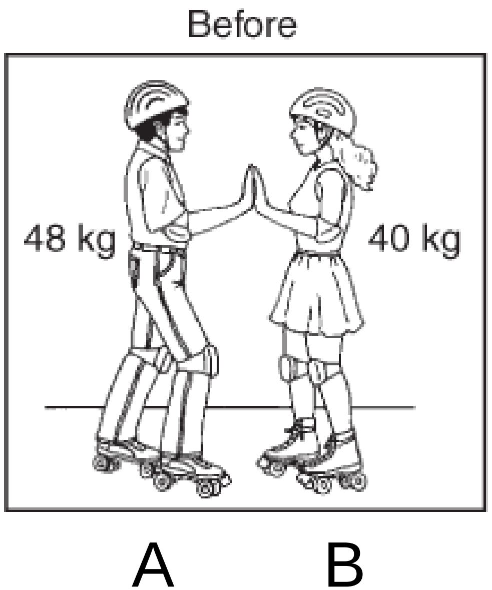
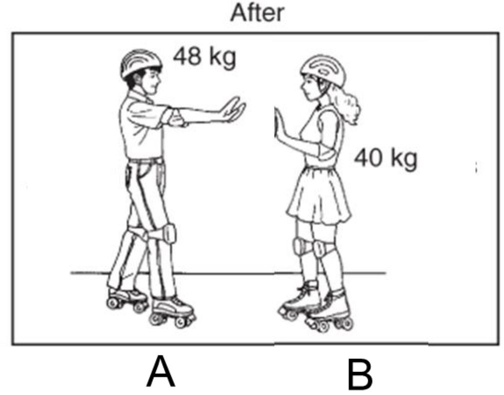
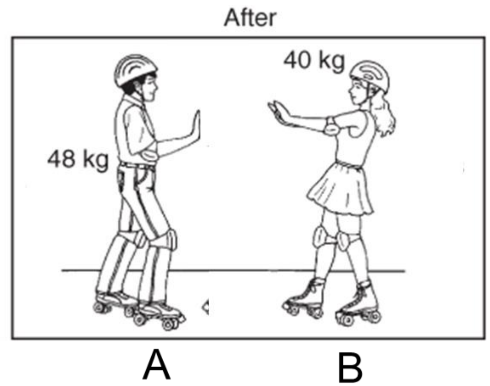


Momentum Conservation

Emergence







Both A and B move with the same momentum *(magnitude)*

Fun with Math

What is A,B,C?

Write on whiteboard ranking with DECREASING magnitude

BDAC

$$A = \frac{10^{-25}}{10^{-17}}$$

$$B = \frac{10^{-5}}{10^{-7}}$$

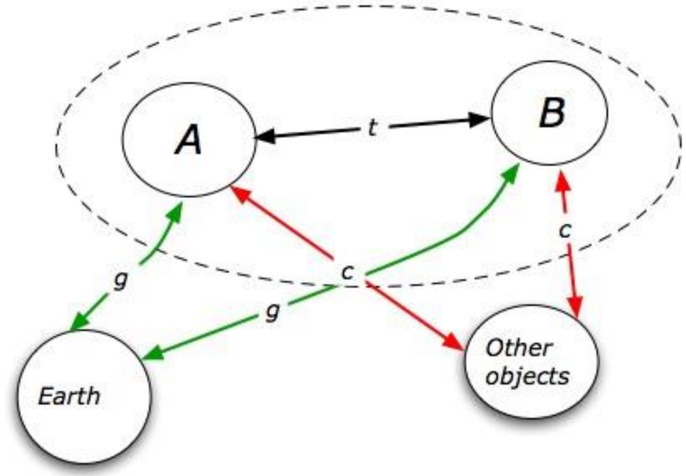
$$C = \frac{10^{-25}}{10^{17}}$$

$$D = 1E-2$$

Whiteboard, TA & LA

Momentum Conservation 2

- If two objects, A and B, interact with each other and with other (“external”) objects,



$$m_A \, \mathrm{D}\vec{v}_A = (\vec{F}_A^{ext} + \vec{F}_{B\to A})\mathrm{D}t$$

$$m_B \, \mathrm{D}\vec{v}_B = (\vec{F}_B^{ext} + \vec{F}_{A\to B})\mathrm{D}t$$

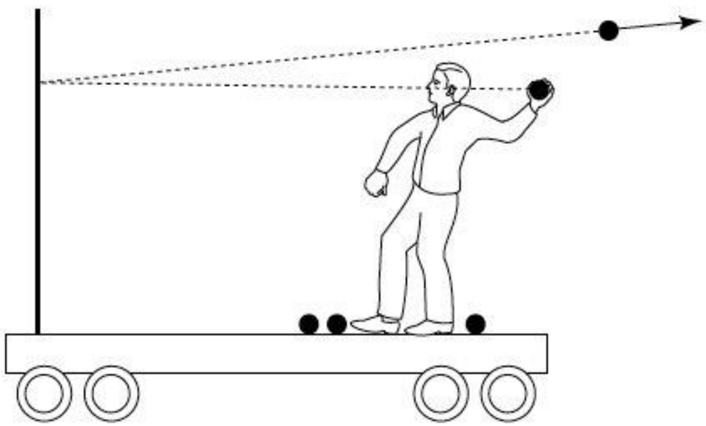
- The total change in momentum of A and B equals the sum of external forces exerted on A and B in a time interval Δt:

$$m_A \, \Delta\vec{v}_A + m_B \, \Delta\vec{v}_B = \left[\vec{F}_A^{ext} + \vec{F}_B^{ext} + \left(\vec{F}_{A\to B} + \vec{F}_{B\to A} \right) \right] \Delta t$$

$$\Delta\left(m_A\vec{v}_A + m_B\vec{v}_B \right) = \left(\vec{F}_A^{ext} + \vec{F}_B^{ext} \right) \Delta t$$

Suppose you are on a cart, initially at rest on a track with negligible friction.

You throw balls at a partition that is rigidly mounted on the cart. The balls bounce straight back as shown in the figure.

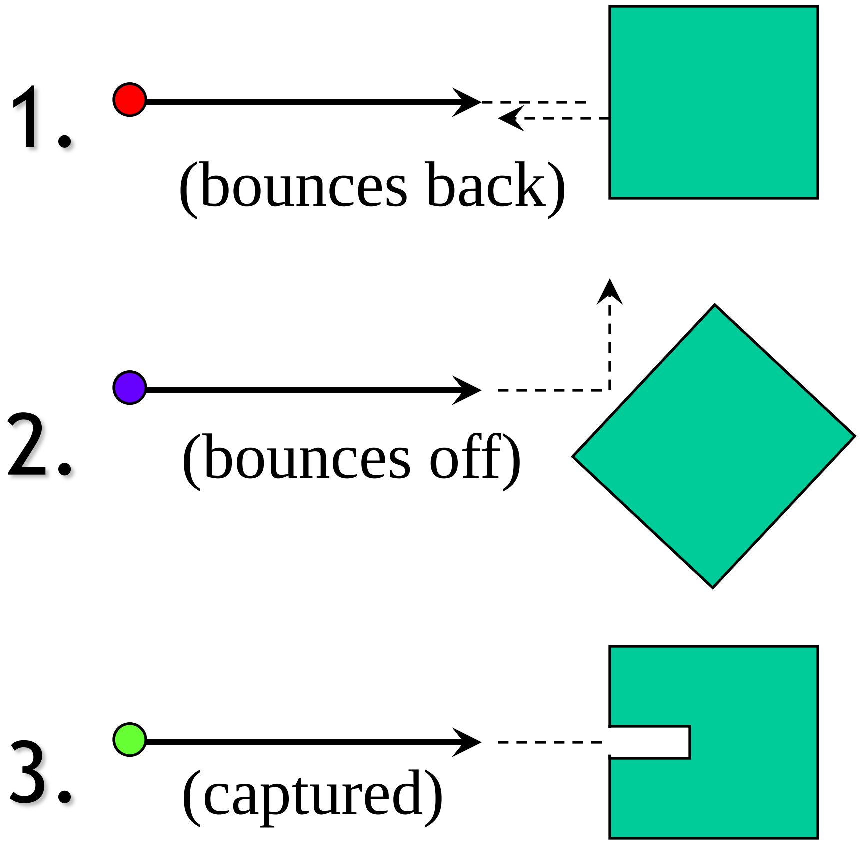


Is the cart put in motion?

(1) Yes. Towards the left
(2) Yes. Towards the right.
(3) No.
(4) You are not given enough information to decide.

Whiteboard, TA & LA

A ball on a table sliding and hitting a block. Which ball exerts the largest impulse on the block?

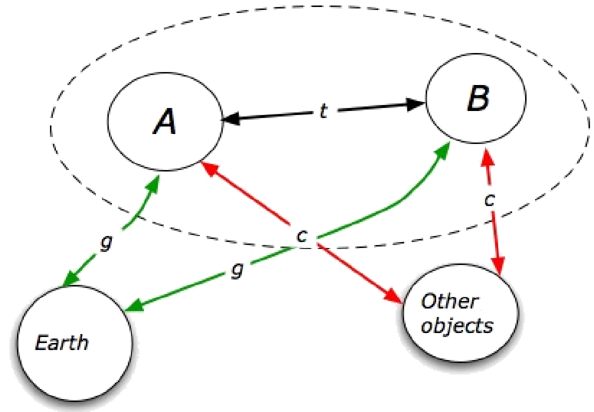


4. Not enough information

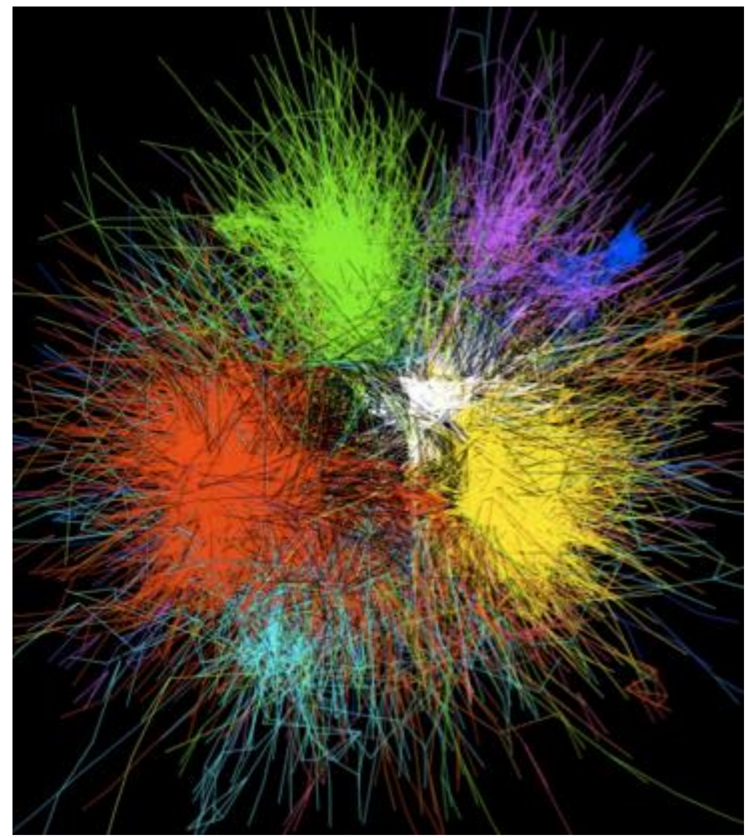
1 has largest change in momentum

Whiteboard, TA & LA

- So far we have studied about 1-5 objects.

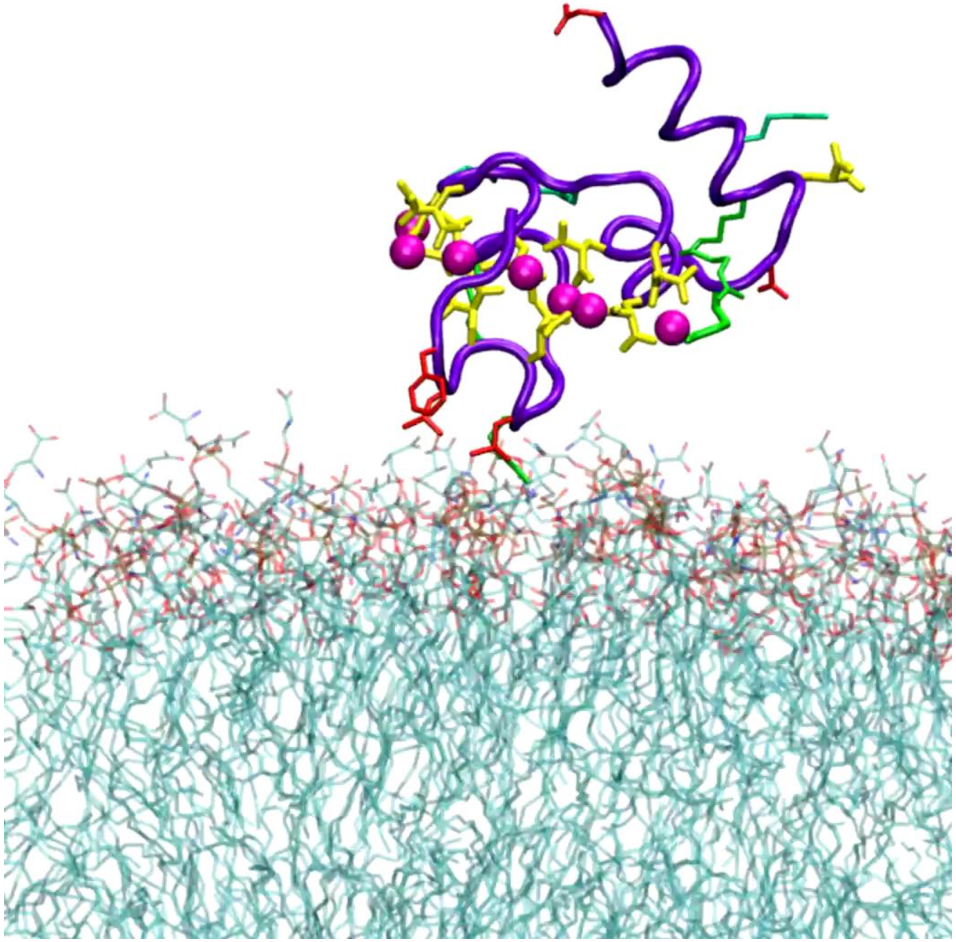


- to study cells, fluids,etc
  - LOTS of objects
  - MANY interactions



An example of something more complex:

Could we use Newton's law when thinking about a specific protein structure/chemical reaction, in determining whether it favors a kinetic or thermodynamic conformation?



Blood clotting protein sitting on membrane

Can we apply Newton's laws to predict the motion of the protein?

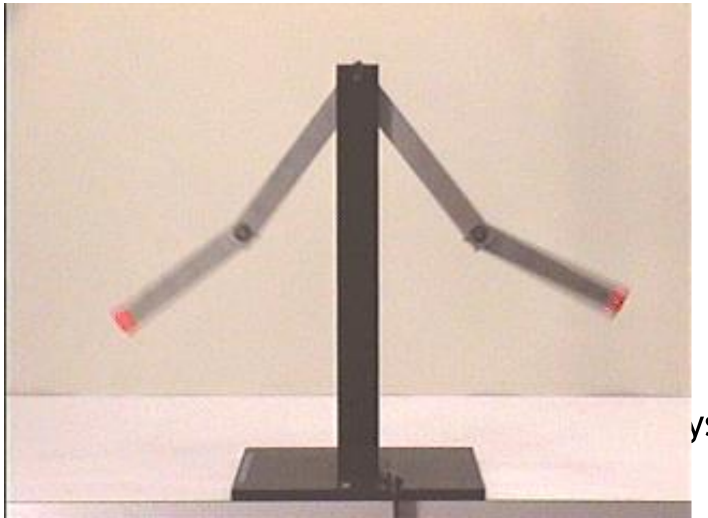
1. No
2. **Yes**
3. Depends

Reading Questions

- Can I think about this process in terms of Newton's laws?
- If the trajectories are unpredictable after a few collisions, what can I say about the motion?
- Is this jiggling really similar to collisions of billard balls? Does it carry momentum? Do collisions exert a force?

- How well can we predict motion when the system gets more complicated?

The Double pendulum example shows that the exact motion can become impossible to predict even for relatively simple systems -> This has led to the field of CHAOS research which aims to develop predictions and models even for chaotic systems

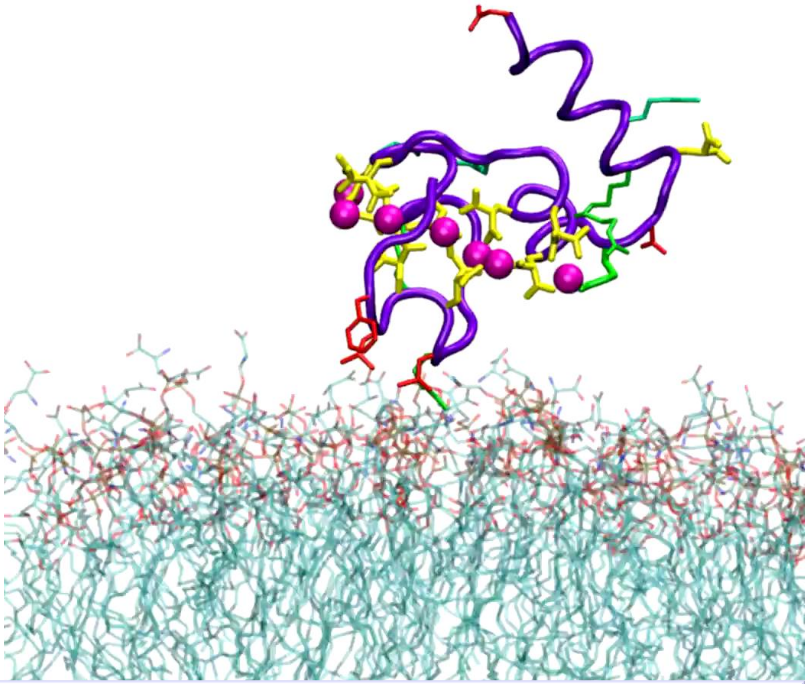


Whiteboard, TA & LA

What can you predict for Chaotic, Complex Systems?

- Even a complex system such as a membrane and protein follow Newton’s laws.
- However, its impossible to predict motion of atoms/molecules accurately after multiple interactions (and interactions are very frequent!)

What could we potentially predict for the motion of the membrane protein?



<u>Could predict:</u>

average shape of protein sitting on membrane; average depth at which protein is embedded in membrane, the amount of fluctuations in shape.

(Alternatively, we could test a model in the simulation: if we had e.g. an energy based model of protein binding probability, we could compare that to the simulation.)

NOTE: The predictions are for STATISTICS – Averages and Fluctuations

Emergent Properties

The question: Can the properties of a system can be explained in terms of the properties of its component parts (so, biology can be explained by chemistry, chemistry by physics)?

Emergence –means that some phenomena are undetectable when looked at “in the small”. They emerge only when looking at the system as a whole rather than its parts.