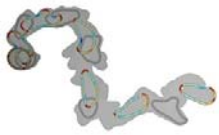
Physics 131- Fundamentals of Physics for Biologists I



Professor: Wolfgang Losert wlosert@umd.edu

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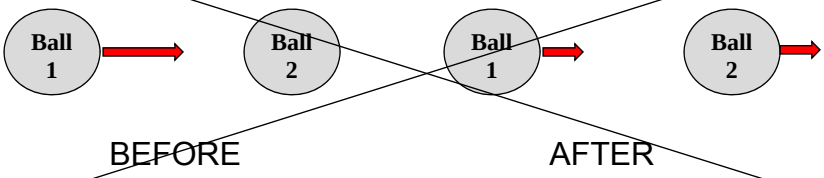
Rube Goldberg Machines **http://www.youtube.com/watch?v=qybUFnY7Y8w**

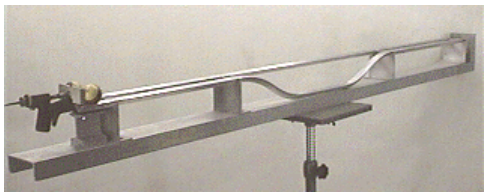
The puzzle

- If momentum conservation was the only principle at work, the initial velocity of ball 1 can be shared with ball 2 (equal mass) in any proportion.

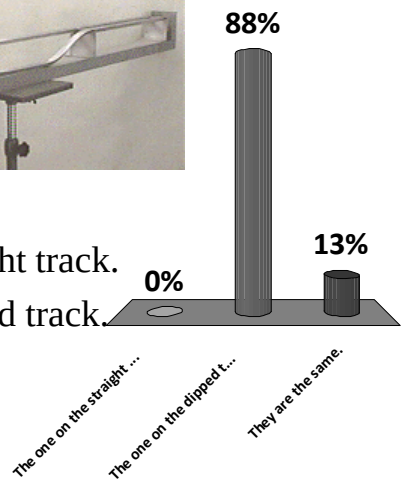


- WHAT ELSE IS CONSERVED?

Both balls are launched at the same speed. Which one gets to the end first?



1. The one on the straight track.
2. The one on the dipped track.
3. They are the same.



Energy

- Newtons 2nd law tells us that a force can change an object's velocity in one of two ways:
  - It can change the speed
  - It can change the direction
- Analyzing changes in speed leads us to study energy.

Kinetic Energy and Work

- Consider an object moving along a line feeling a single force, *F*. When is moves a distance Δ*x*, how much does its speed change?

$$a = F^{net} / m$$

$$\frac{\Delta v}{\Delta t} = \frac{F^{net}}{m}$$

$$\frac{\Delta v}{\Delta t}\Delta x = \frac{F^{net}}{m}\Delta x$$

$$\Delta v \frac{\Delta x}{\Delta t} = \frac{F^{net}\Delta x}{m}$$

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$$\Delta v \frac{\Delta x}{\Delta t} = \frac{F^{net}\Delta x}{m}$$

$$\langle v \rangle \Delta v = \frac{F^{net}\Delta x}{m}$$

$$\frac{v_i + v_f}{2}(v_f - v_i) = \frac{F^{net}\Delta x}{m}$$

$$\tfrac{1}{2}(v_f^2 - v_i^2) = \frac{F^{net}\Delta x}{m}$$

$$\tfrac{1}{2} m(v_f^2 - v_i^2) = F^{net}\Delta x$$

Definitions:

Kinetic energy = $\frac{1}{2}mv^2$

Work done by a force *F* = $F\ \Delta x$

Result

$$\Delta(\tfrac{1}{2}mv^2) = F^{net}\ \Delta x$$

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Foothold ideas: Kinetic Energy and Work

- Newton's laws tell us how velocity changes. The Work-Energy theorem tells us how speed (independent of direction) changes.
- Kinetic energy = $\frac{1}{2}mv^2$
- Work done by a force = $F_x \Delta x$ or $F_{||} \Delta r$ (part of force || to displacement)
- Work-energy theorem: $\Delta(\frac{1}{2}mv^2) = F_{||}^{net} \Delta r$

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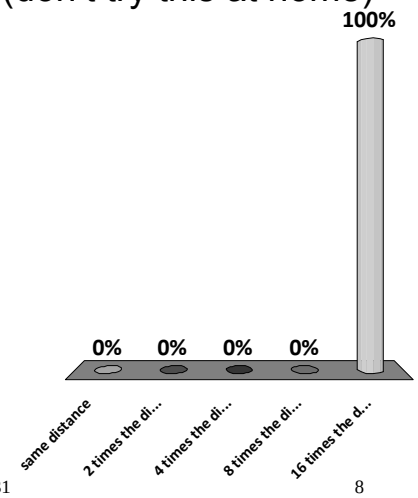
When you go 80 mph on the beltway rather than 20 mph on campus, when you slam on the breaks as hard as you can, how much further do you skid on the beltway than on campus? (don't try this at home)

1. same distance
2. 2 times the distance
3. 4 times the distance
4. 8 times the distance
5. 16 times the distance



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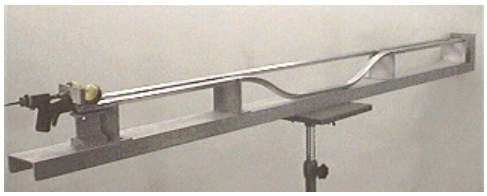
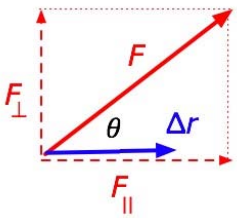
Both balls are launched at the same speed. Which one moves faster at the end?



1. The one on the straight track.
2. The one on the dipped track.
3. They have the same speed.

Work in another direction: The dot product

- Suppose we are moving along a line, but the force we are interested in in pointed in another direction? (How can this happen?)
- Only the part of the force in the direction of the motion counts to change the speed (energy).



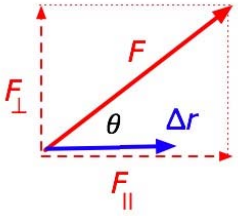
$$\text{Work} = F_{\parallel}\,\Delta r = F\cos\theta\,\Delta r \equiv \vec{F}\cdot\Delta\vec{r}$$

Dot products in general

$$F_{\parallel}\,\Delta r \equiv \vec{F}\cdot\Delta\vec{r} \qquad \vec{F}\cdot\Delta\vec{r} = F\cos\theta\,\Delta r$$

In general, for any two vectors that have an angle θ between them, the dot product is defined to be $\vec{a}\cdot\vec{b} = ab\cos\theta$

$$\vec{a}\cdot\vec{b} = a_x b_x + a_y b_y$$



The dot product is a scalar.
Its value does not depend on the coordinate system we select.

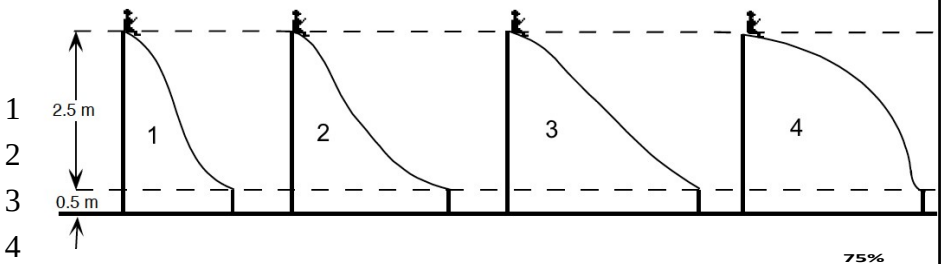
Each row in the following table pairs a force vector with a corresponding displacement resulting in work *W* being done. In which of these rows is the work done zero?

	$\vec{F}$	$\Delta\vec{r}$
1.	→	←
2.	←	←
3.	↑	→
4.	↖	→
5.	↓	↖

Each row in the following table pairs a force vector with a corresponding displacement resulting in work *W* being done. In which of these rows is the work done positive?

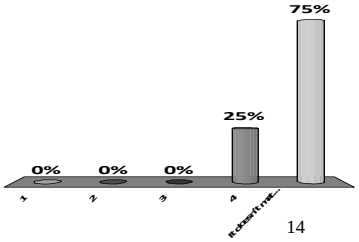
	$\vec{F}$	$\Delta\vec{r}$
1.	→	←
2.	←	←
3.	↑	→
4.	↖	→
5.	↓	↙

A young girl wants to select one of the (frictionless) playground slides illustrated below to give her the greatest possible speed when she reaches the bottom of the slide. Which should she choose?

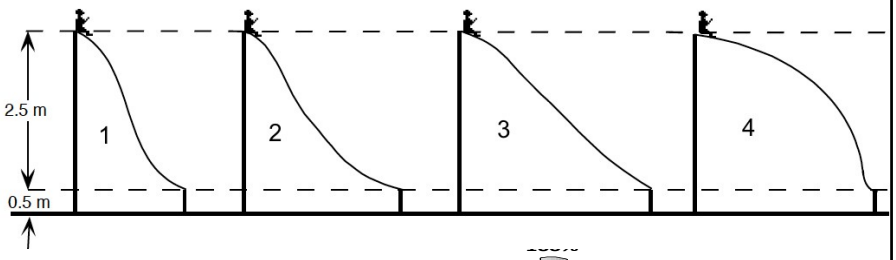


1
2
3
4

It doesn't matter. It would be the same for each.



A young girl wants to select one of the (frictionless) playground slides illustrated below to get her to the bottom of the slide fastest. Which should she choose?



1
2
3
4

It doesn't matter. It would be the same for each.