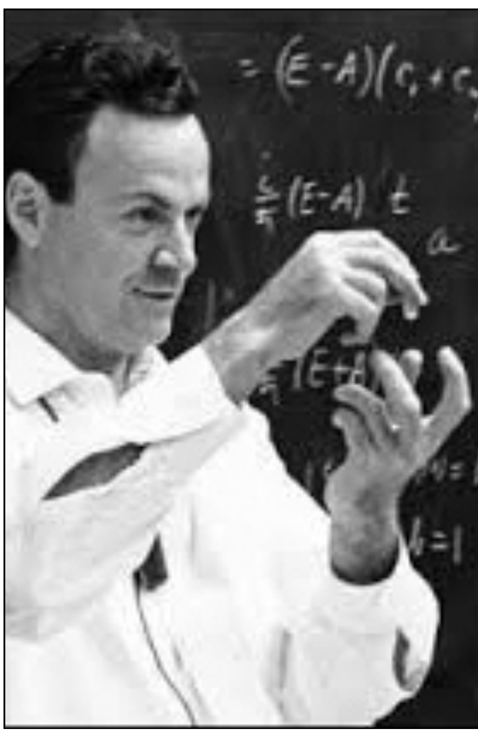
November 18, 2016 Physics 131 Prof. E. F. Redish

- **Theme Music:** **Earth, Wind, & Fire**

  Energy

- **Cartoon:** **Bob Mankoff**

"Counsellor, please advise your client that, issues of personal safety aside, gravity is the law."



The Equation of the Day

Potential energy

$$\Delta U^{gravity} = \Delta(mgh)$$

$$\Delta U^{spring} = \Delta\left(\tfrac{1}{2}k(\Delta L)^2\right)$$

$$\Delta U^{spring} = \Delta\left(\frac{k_C qQ}{r}\right)$$

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: $\Delta(\frac{1}{2}mv^2) = \vec{F}^{net} \cdot \Delta\vec{r}$

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Momentum vs. energy

- If we change the motion of two interacting objects so the momentum of each changes in the same way, it might be useful to look at the KE in terms of that momentum.
- Suppose each starts with p =0 and they only move as a result of each other's forces.

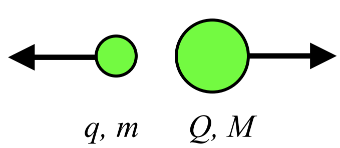
$$\vec{p}_A = \Delta\vec{p}_A = -\Delta\vec{p}_B = -\vec{p}_B$$

$$KE_A = \tfrac{1}{2}m_A v_A^2 = \tfrac{1}{2}\frac{(m_A^2 v_A^2)}{m_A} = \frac{p_A^2}{2m_A}$$

$$KE_B = \tfrac{1}{2}m_B v_B^2 = \tfrac{1}{2}\frac{(m_B^2 v_B^2)}{m_B} = \frac{p_B^2}{2m_B}$$

If each object gets the same momentum, which has bigger KE?

1. The object with the bigger mass.
2. The object with the smaller mass.
3. They will have the same KE.



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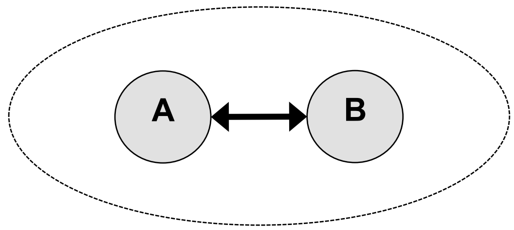
Simplest example:

Consider the motion of two objects during a short time interval while they exert forces on each other.

Momentum change?
Impulse-momentum theorem!

$$\Delta\vec{p}_A = \vec{F}_{B\to A}\Delta t$$
$$\Delta\vec{p}_B = \vec{F}_{A\to B}\Delta t$$



Add and use N3!

$$\Delta\vec{p}_A + \Delta\vec{p}_B = \vec{F}_{B\to A}\Delta t + \vec{F}_{A\to B}\Delta t = (\vec{F}_{B\to A} + \vec{F}_{A\to B})\Delta t = 0$$

Momentum Conservation!

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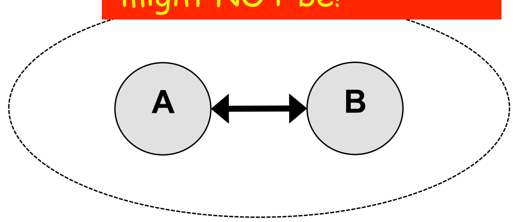
Simplest example:

Consider the motion of two objects during a short time interval while they exert forces on each other.

KE change?
Work-energy theorem!

They may each be moving so although the times are the same,the distances might NOT be!

$$\Delta KE_A = \vec{F}_{B\to A}\cdot\Delta\vec{r}_A$$
$$\Delta KE_B = \vec{F}_{A\to B}\cdot\Delta\vec{r}_B$$



Add and use N3!

$$\Delta KE_A + \Delta KE_B = \vec{F}_{B\to A}\cdot\Delta\vec{r}_A + \vec{F}_{A\to B}\cdot\Delta\vec{r}_B$$
$$= \vec{F}_{B\to A}\cdot\left(\Delta\vec{r}_A - \Delta\vec{r}_B\right) \neq 0$$

??!

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Foothold ideas: Potential Energy

- **For some forces** between objects (gravity, electricity, springs) the work only depends of the change in relative position of the objects. Such forces are called *conservative*.
- For these forces the work done by them can be written

$$\vec{F} \cdot \Delta\vec{r}_{rel} = -\Delta U$$

- *U* is called a *potential energy* and can be considered an *energy of place belonging to the two objects that can be exchanged with KE.*

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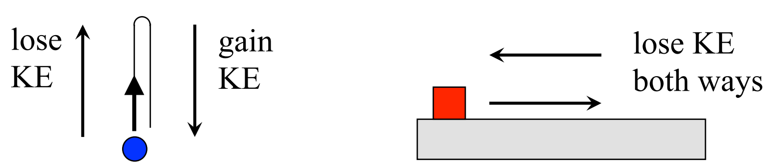
Conservative forces

- Forces (like gravity or springs) are conservative if when the force takes KE away, you can get it back when you go back to where you started.
- If the kinetic energy that a force takes away can't be restored by going back to where you started it is called non-conservative.
- Compare gravity and friction:



11/1[…] Gravity: Conservative Physics Friction: Non-Conservative

Foothold ideas: Potential Energy

- For some forces work only depends on the change in position. Then the work done can be written

$$\vec{F} \cdot \Delta\vec{r} = -\Delta U$$

U is called a *potential energy*.

- Gravity, $U_{gravity} = mgh$

Flat-earth gravity approximation

Spring, $U_{spring} = \frac{1}{2} k(\Delta L)^2$

Hooke's law approximate model

Electric Force, $U_{electric} = k_C Q_1 Q_2 / r_{12}$

Exact for point charges

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