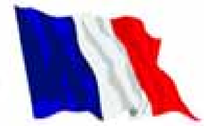
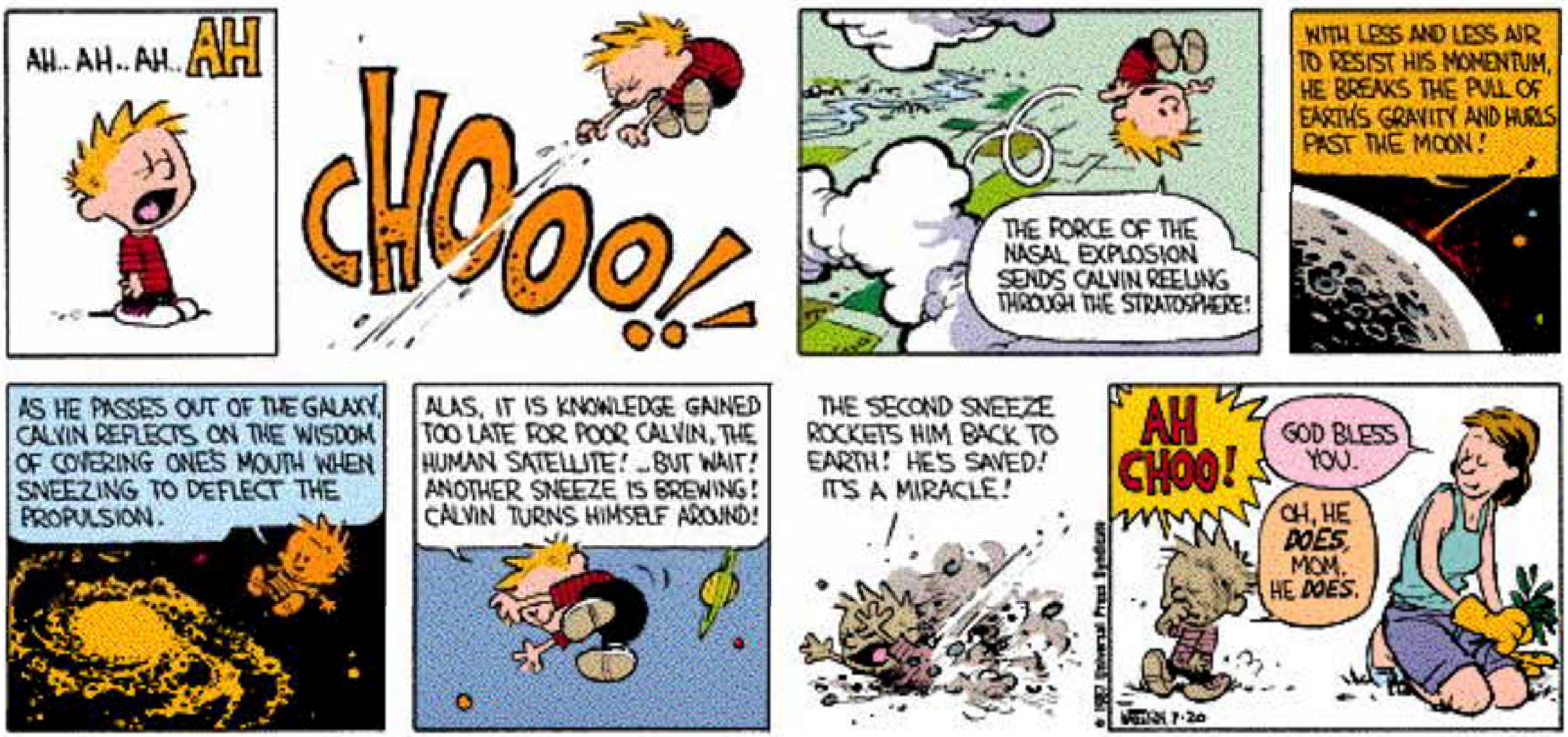
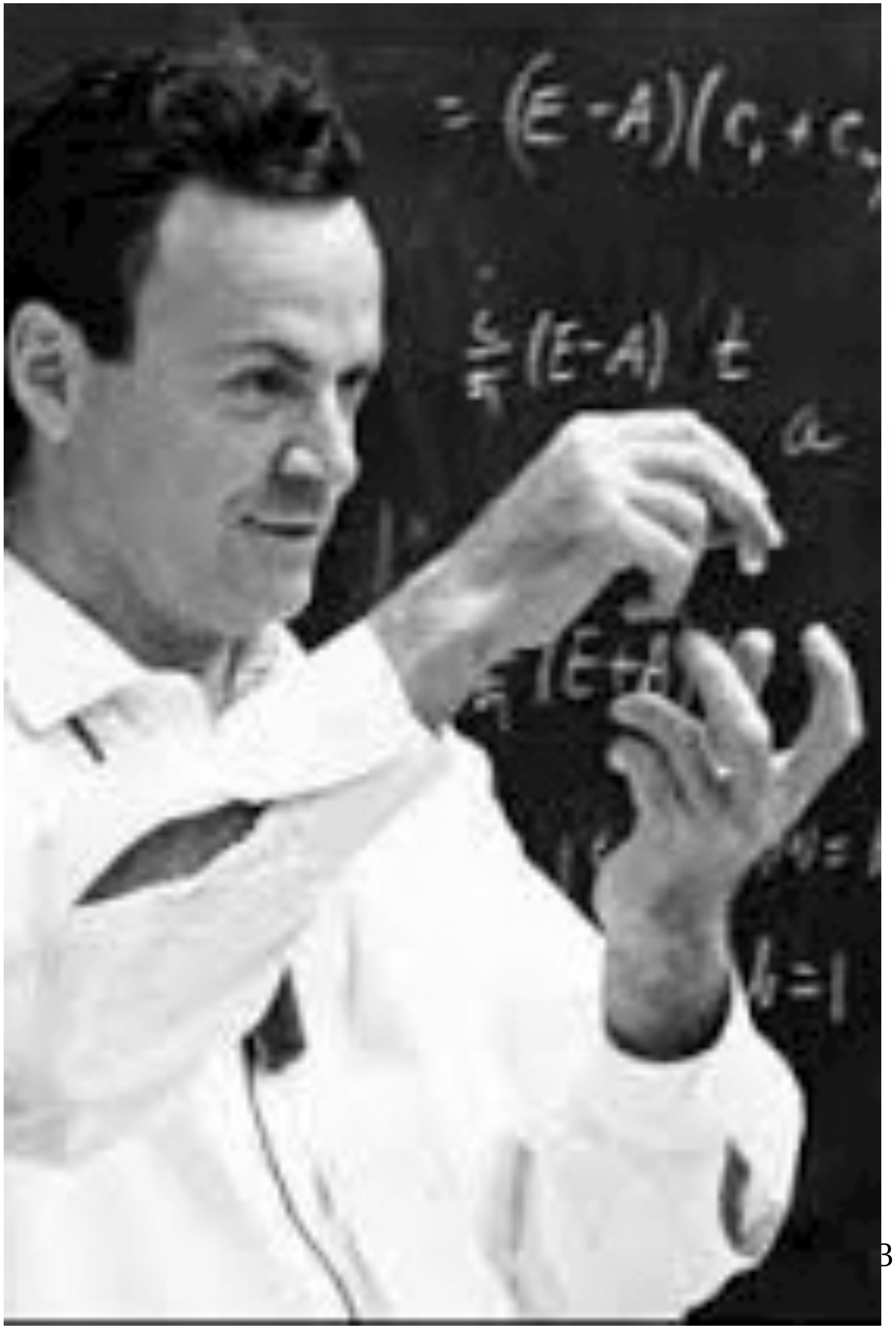
- **<u>Theme Music:</u> Edit Piaf**
  Sous le ciel de Paris



- **<u>Cartoon:</u> Bill Watterson**
  Calvin & Hobbes





The Equation of the Day

Potential energy

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

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

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

Physics 131

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

Simplest example:

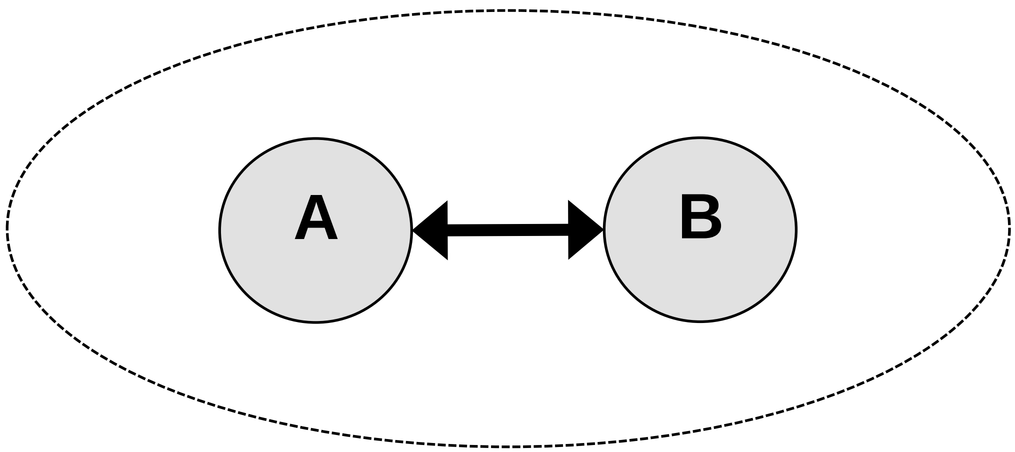
Consider the motion of two objects during a short time interval while they exert forces on each other.

Momentum change?

Impulse-momentum theorem!

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

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



Add and use N3!

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

Momentum Conservation!

Simplest example:

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

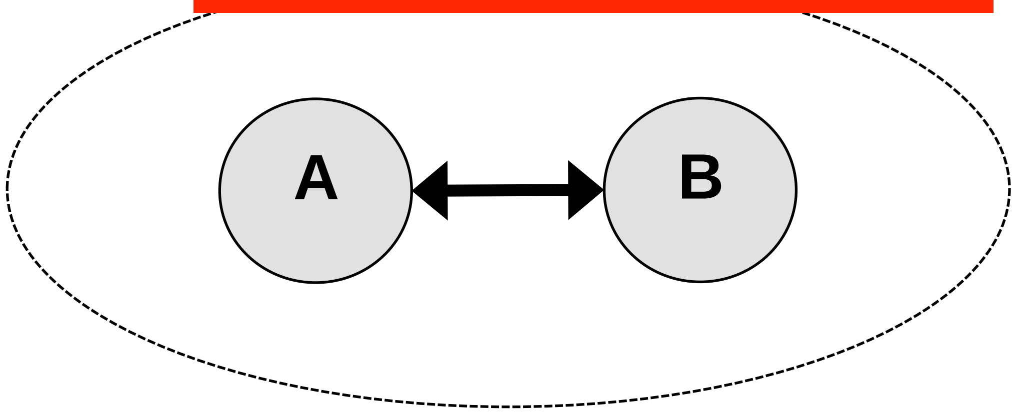
KE change?

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!

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

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

??!

Dimensions and Units of Energy

- $[1/2\ mv^2] = M\text{-}(L/T)^2 = ML^2/T^2$
- $1\ kg\text{-}m^2/s^2 = 1\ N\text{-}m = 1$ Joule
- Other units of energy are common (and will be discussed later)
  - Calorie
  - eV (electron Volt)
  - erg ($=1\ g\text{-}cm^2/s^2$)

Power

- An interesting question about work and energy is the rate at which energy is changed or work is done. This is called *power*.

$$\text{Power} = \frac{\text{Energy change}}{\text{time to make the change}}$$

$$= \frac{\Delta W}{\Delta t} = \vec{F}^{\,net} \cdot \frac{\Delta \vec{r}}{\Delta t} = \vec{F}^{\,net} \cdot \vec{v} \quad \text{(for mechanical work)}$$

- Unit of power

1 Joule/sec = 1 Watt

Foothold ideas: Potential Energy

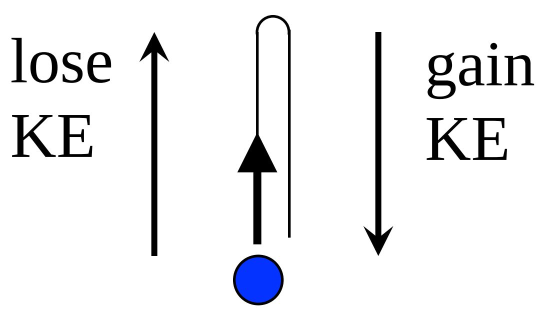
- For some forces between objects (gravity, electricity, springs) the work only depends of the change in relative position of the objects. Such forces are called *conservative*.
- For these forces the work done by them can be written

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

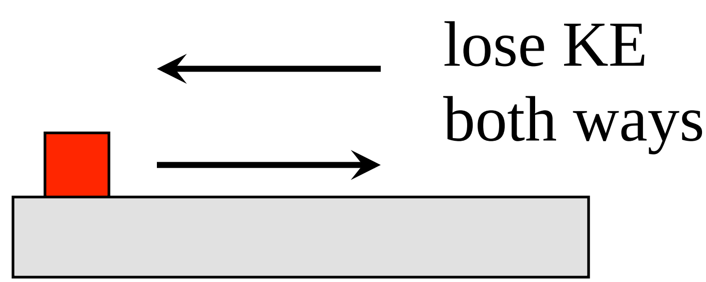
- *U* is called a *potential energy* and is an *energy of place belonging to the interaction of two objects that can be exchanged with their KE.*

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 <u>can't</u> be restored by going back to where you started it is called non-conservative.
- Compare gravity and friction:



Gravity: Conservative



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*.

- For gravity, $U_{gravity} = mgh$

  For a spring, $U_{spring} = \frac{1}{2} kx^2$

  For electric force, $U_{electric} = k_C Q_1 Q_2 / r_{12}$

Foothold ideas: Conservation of Mechanical Energy

- Mechanical energy
  – The mechanical energy of a system of objects is conserved if resistive forces can be ignored.

$$\Delta\left(KE + PE\right) = 0$$

$$KE_{initial} + PE_{initial} = KE_{final} + PE_{final}$$

This is why we define the PE with a negative sign.

- Thermal energy
  – Resistive forces transform coherent energy of motion (energy associated with a net momentum) into *thermal energy* (energy associated with internal chaotic motions and no net momentum)