PHYS 210 - General Physics I

- Work – energy theorem
- Power
- Elastic collisions
- The SHO & SHM

Example:

A cave rescue team lifts an injured spelunker directly upward and out of a sinkhole by means of a motor-driven cable. The lift is performed in three stages, each requiring a vertical distance of 10.0 meters:

(a) the initially stationary spelunker is accelerated to a speed of 5.00 m/s,

(b) she is then lifted at the constant speed of 5.00 m/s,

(c) finally, she is decelerated to zero speed.

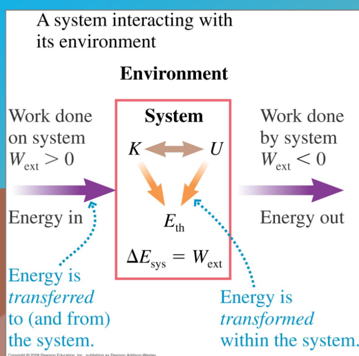
How much work is done on the 80.0 kg rescuee by the force lifting her during each stage?

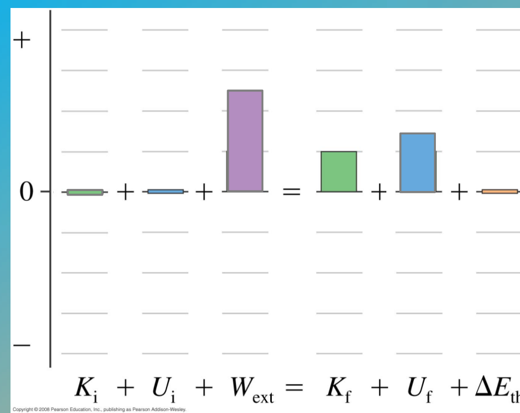
THE LAW OF CONSERVATION OF ENERGY

Energy transformations:

A rope lifts a spelunker at an increasing speed.

W_{ext} is the work done on the system by the force exerted by the rope.



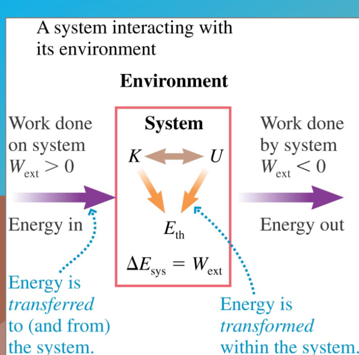


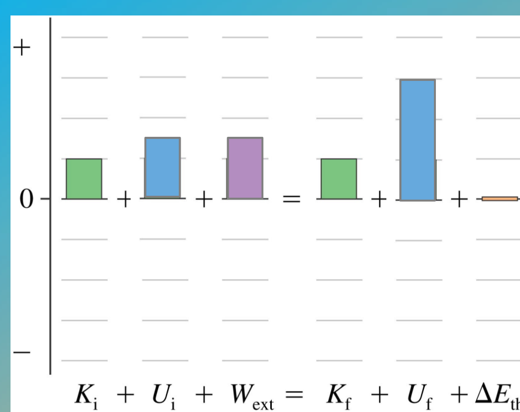
THE LAW OF CONSERVATION OF ENERGY

Energy transformations:

A rope lifts a spelunker at a constant speed.

W_{ext} is the work done on the system by the force exerted by the rope.

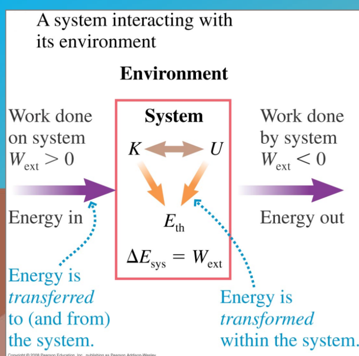


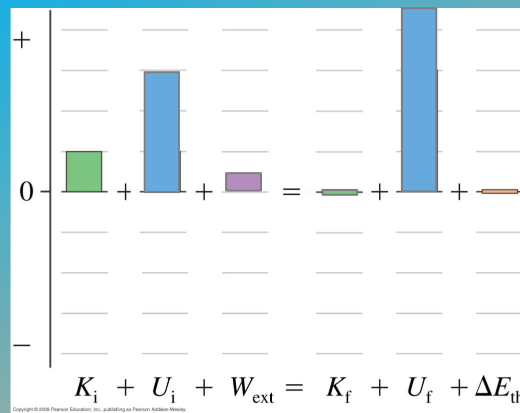


THE LAW OF CONSERVATION OF ENERGY

Energy transformations:

- A rope lifts a spelunker at a decreasing speed.
- W_{ext} is the <u>work done on the system</u> by the force exerted by the rope.





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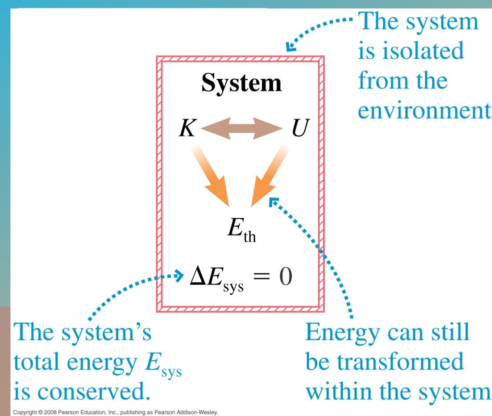
How much work is done on the 80.0 kg rescuee by the force lifting her during each stage?

THE LAW OF CONSERVATION OF ENERGY

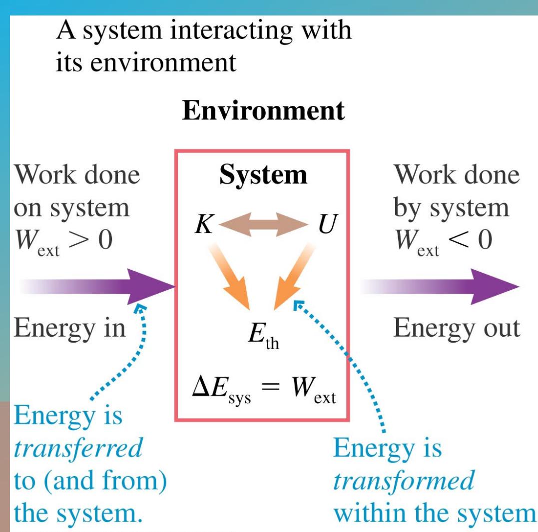
For an isolated system



THE LAW OF CONSERVATION OF ENERGY

in general:

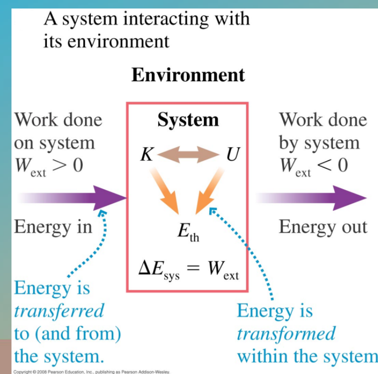
$$\Delta K + \Delta U + \Delta E_{th} = \Delta E_{mech} + \Delta E_{th} = \Delta E_{system} = W_{ext}$$



THE LAW OF CONSERVATION OF ENERGY

For modeling the general case:

$$K_f + U_f + \Delta E_{th} = K_i + U_i + W_{ext}$$



POWER

The RATE at which work is done by a force (rate at which energy is expended) is the (instantaneous) power, P:

$$P = \frac{dW}{dt} = \vec{F} \cdot \vec{v}$$

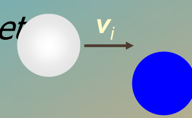
The units of P are W = J/s

Elastic vs. Inelastic Collisions

- A collision is said to be *elastic* when kinetic energy as well as momentum is conserved before and after the collision:

$$KE_{before} = KE_{after}$$

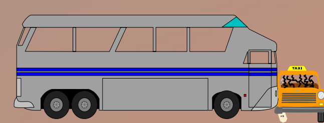
  - *E.g.,* carts colliding with a spring in between, billiard balls, *etc.*



- A collision is said to be *inelastic* when energy is not conserved before and after the collision, but momentum is conserved:

$$KE_{before} \neq KE_{after}$$

  - *E.g.*, car crashes, collisions where objects stick together, *etc.*

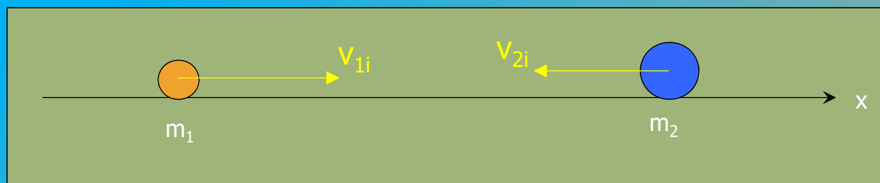


Elastic Collisions

During an elastic collision, kinetic energy and linear momentum are both conserved.

$$\vec{P}_i = \vec{P}_f \qquad K_i = K_f$$

Elastic Collisions – the general 1-D case



Using conservation of momentum and kinetic energy, the final speeds are given by

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i} + \frac{2m_2}{m_1 + m_2} v_{2i}$$

$$v_{2f} = \frac{m_2 - m_1}{m_1 + m_2} v_{2i} + \frac{2m_1}{m_1 + m_2} v_{1i}$$

SHM (the SHO)

- Simple harmonic motion approximates many, many physical systems!
- Terms associated with SHM:
  - Hooke's Law = $F = -kx$, where k is the ...
  - frequency = f
  - period = $T = 1/f$
  - amplitude = x_m
  - angular frequency = $\omega = 2\pi/T = 2\pi f$
  - phase constant = φ
  - displacement = $x = x_m \cos(\omega t + \varphi)$

SHO

- The solution to the SHO differential equation,

$$m\frac{d^2x}{dt^2} = -k\,x$$

is

$$x(t) = A\cos(\omega t + \phi)$$

SHO - Oscillation

- Relate to potential energy "wells" and turning points.

$$U_s = \frac{1}{2}k\,x^2$$

- With no friction ("damping"), mechanical energy is conserved: $K + U_s =$ *constant*
- Linear oscillations (motion in regions where Hooke's Law is valid) depend on *k* and *m:*

$$\omega = \sqrt{\frac{k}{m}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

Happy Wednesday!