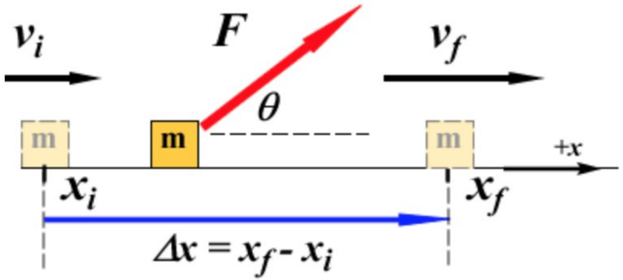
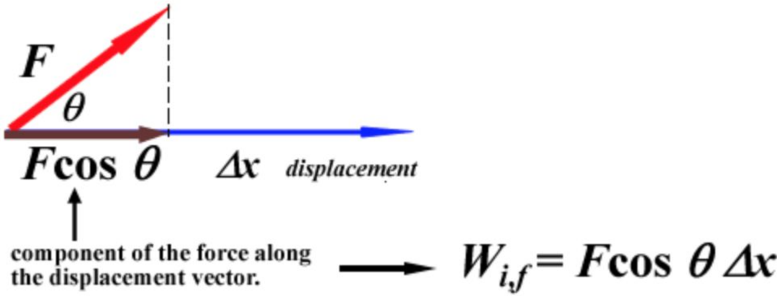
Work and Energy

Fun With Fiziks

Work





- Work is the action done on an object that displaces the object
- Joules = N (force) * m (distance)
- W = F * d
- W = F • d = F * d * cosθ if force is at an angle
  - Dot product definition: A • B = ||A|| * ||B|| * cosθ
  - Dot product of displacement and force vector

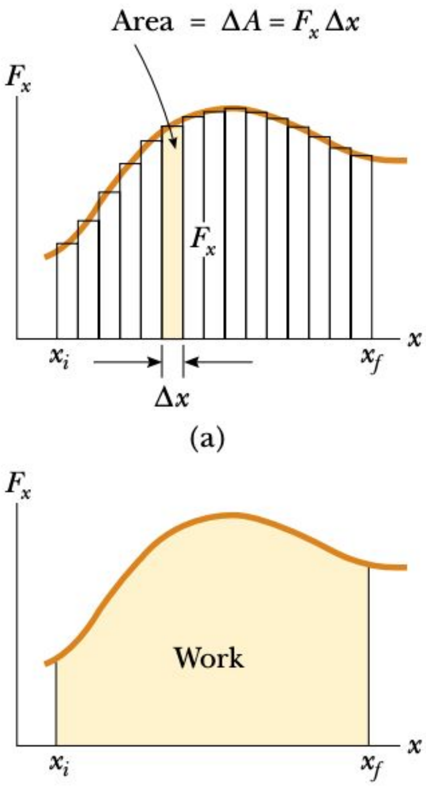
Work cont.

- Work done by a varying force:

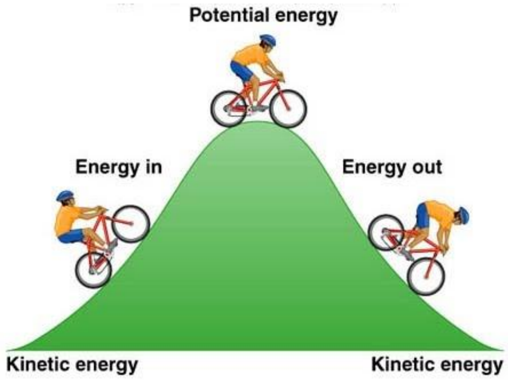
$$W = \int_{x_i}^{x_f} F_x \, dx$$

  - Force is a function of distance F(x)
    - For each step dx, dW = F(x)dx
    - Add up works using integral
  - Work is area under force vs. distance curve
- Example: spring
  - F = -kx → W = 1/2kx^2

$$W_s = \int_{x_i}^{x_f} F_s \, dx = \int_{-x_{max}}^{0} (-kx) \, dx = \frac{1}{2} k x_{max}^2$$

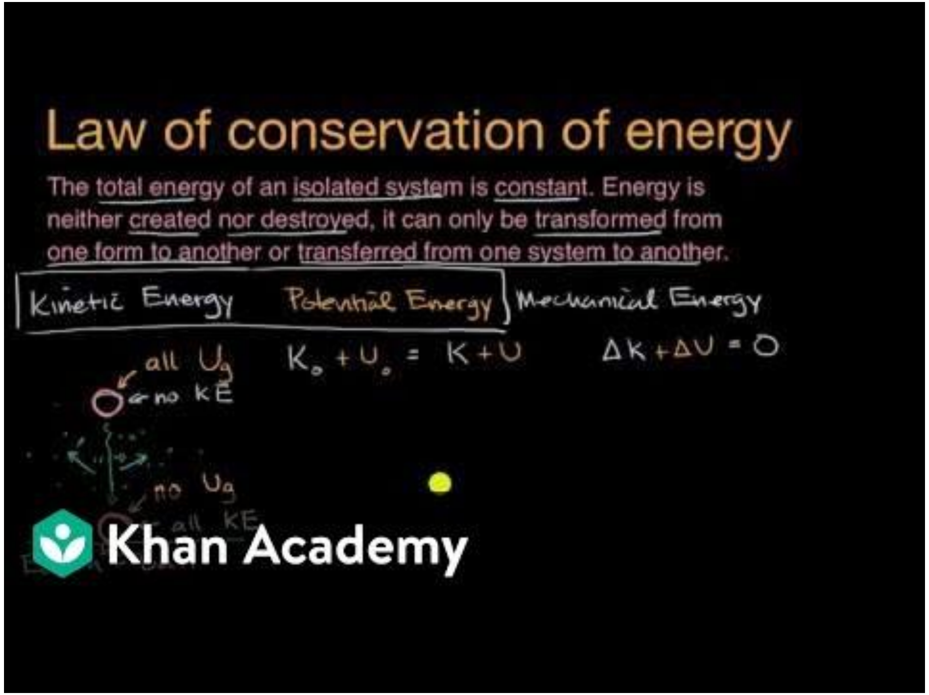


Energy

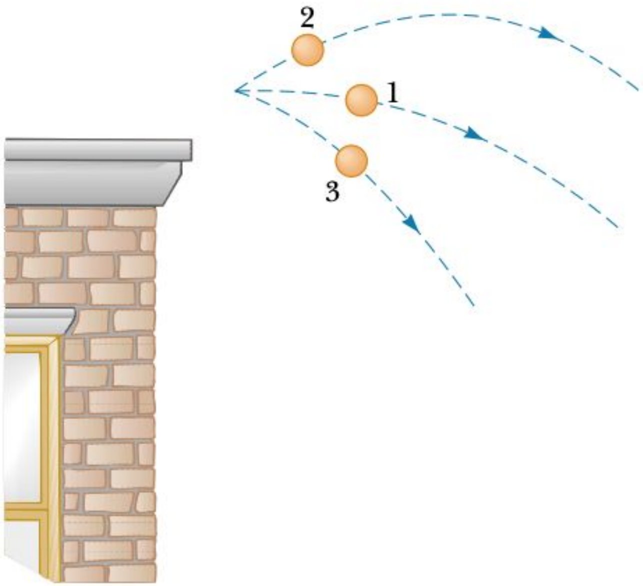


- Energy is the capacity to do work
- Energy is conserved in a closed system: $E_i = E_f$
  - No external forces (ex: friction, air resistance)
  - If there are external forces: $E_i + \Delta E = E_f$ or $\Delta E = E_f - E_i$
- **Kinetic energy (KE):** energy of moving objects
  - KE = 1/2mv^2
- **Potential energy (PE):** stored energy
  - **Gravitational PE:** energy stored in an object by height
    - PE = mgh
  - **Elastic PE:** energy stored in a compressed spring/rubber band/elastic object
    - PE = 1/2kx^2
    - k = spring constant, x = compression distance

Conservation Of Energy



Three identical balls are thrown from the top of a building, all with the same initial speed. The first is thrown horizontally, the second at some angle above the horizontal, and the third at some angle below the horizontal, as shown in Figure 8.5. Neglecting air resistance, rank the speeds of the balls at the instant each hits the ground.



Same velocity for all 3 balls because initial energies are all the same

$E_i = 1/2mv_i$^2 + mgh = E_f

Figure 8.5 Three identical balls are thrown with the same initial speed from the top of a building.

Work-Energy Theorem

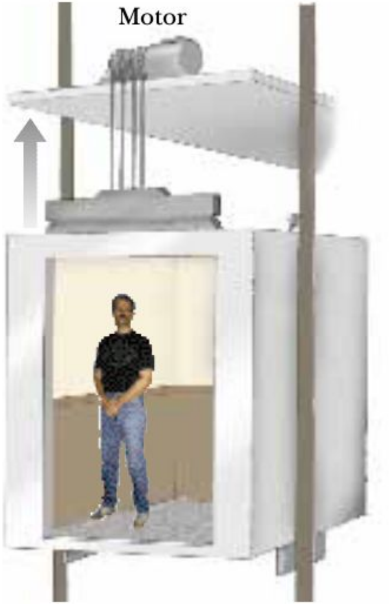
Work-Energy Theorem cont.

- $W = \Delta K = K_f - K_i$
- $W = -\Delta U = U_i - U_f$ for conservative forces
  - Ex: gravity, spring force
  - **Conservative force:** work done between 2 points is independent from path the object takes
  - **Non-conservative force (ex: friction):** work done between 2 points depends on path the object takes
- $W = \Delta E$ in general
- When there is friction:
  - $\Delta E = -fd$

Power

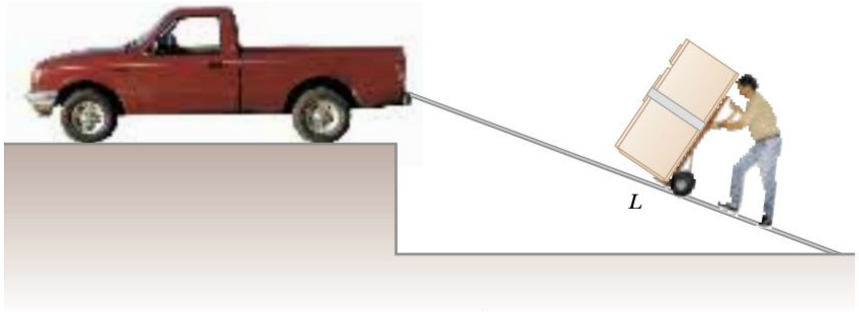
- Measures the rate at which someone/something does work
- Measured in watts (W)
    - Joules/second
    - Also measured in horsepower (hp)
        - 1 hp = 746 W
- $P = W/t$
- $P = F \bullet v$

An elevator car has a mass of 1 000 kg and is carrying passengers having a combined mass of 800 kg. A constant frictional force of 4 000 N retards its motion upward, as shown in Figure 7.18a. (a) What must be the minimum power delivered by the motor to lift the elevator car at a constant speed of 3.00 m/s?

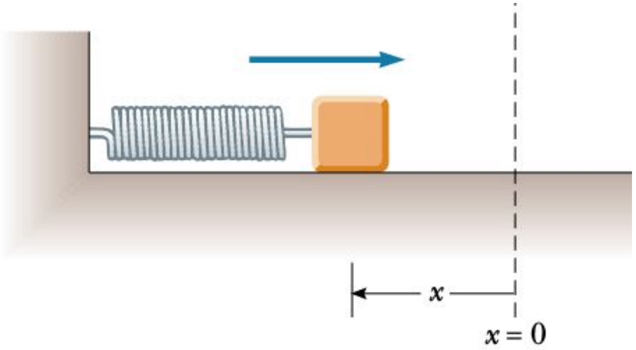


Practice Problems

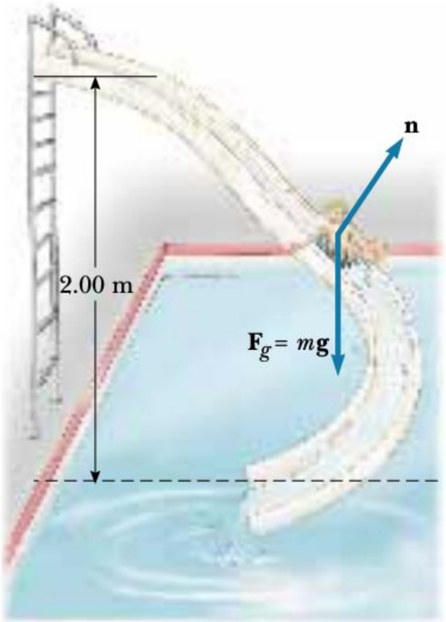
A man wishes to load a refrigerator onto a truck using a ramp, as shown in Figure 7.17. He claims that less work would be required to load the truck if the length L of the ramp were increased. Is his statement valid?



A block of mass 1.6 kg is attached to a horizontal spring that has a force constant of 1.0×10^3 N/m, as shown in Figure 7.10. The spring is compressed 2.0 cm and is then released from rest. (a) Calculate the speed of the block as it passes through the equilibrium position $x = 0$ if the surface is frictionless.

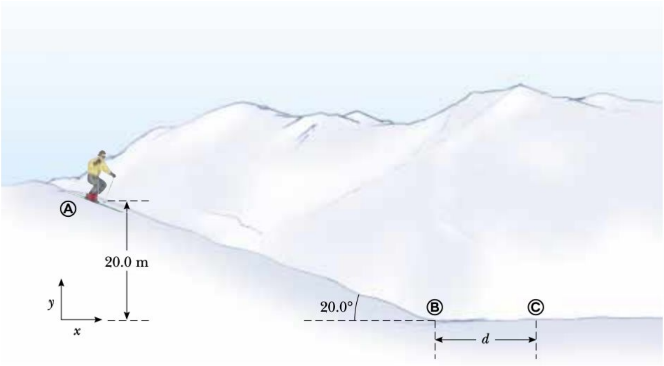


A child of mass m rides on an irregularly curved slide of height $h = 2.00$ m, as shown in Figure 8.9. The child starts from rest at the top. (a) Determine his speed at the bottom, assuming no friction is present.

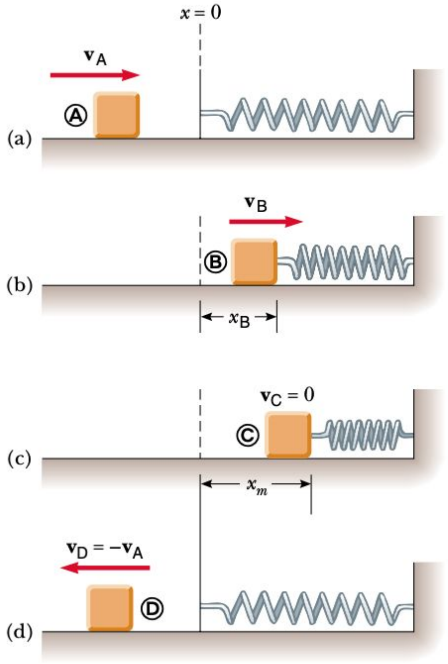


(b) If a force of kinetic friction acts on the child, how much mechanical energy does the system lose? Assume that $v_f = 3.00$ m/s and $m = 20.0$ kg.

A skier starts from rest at the top of a frictionless incline of height 20.0 m, as shown in Figure 8.10. At the bottom of the incline, she encounters a horizontal surface where the coefficient of kinetic friction between the skis and the snow is 0.210. How far does she travel on the horizontal surface before coming to rest?



A block having a mass of 0.80 kg is given an initial velocity $v_A = 1.2$ m/s to the right and collides with a spring of negligible mass and force constant $k = 50$ N/m, as shown in Figure 8.12. (a) Assuming the surface to be frictionless, calculate the maximum compression of the spring after the collision.



(b) Suppose a constant force of kinetic friction acts between the block and the surface, with $\mu_k = 0.50$. If the speed of the block at the moment it collides with the spring is $v_A = 1.2$ m/s, what is the maximum compression in the spring?