PHYSICS I

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CONSERVATION OF ENERGY

Ways to Transfer Energy Into or Out of A System

In non-isolated systems, energy crosses the boundary of the system during some time interval due to an interaction with the environment.

Work – transfers energy by applying a force and causing a displacement of the point of application of the force.

Mechanical Wave – transfers energy by allowing a disturbance to propagate through a medium.

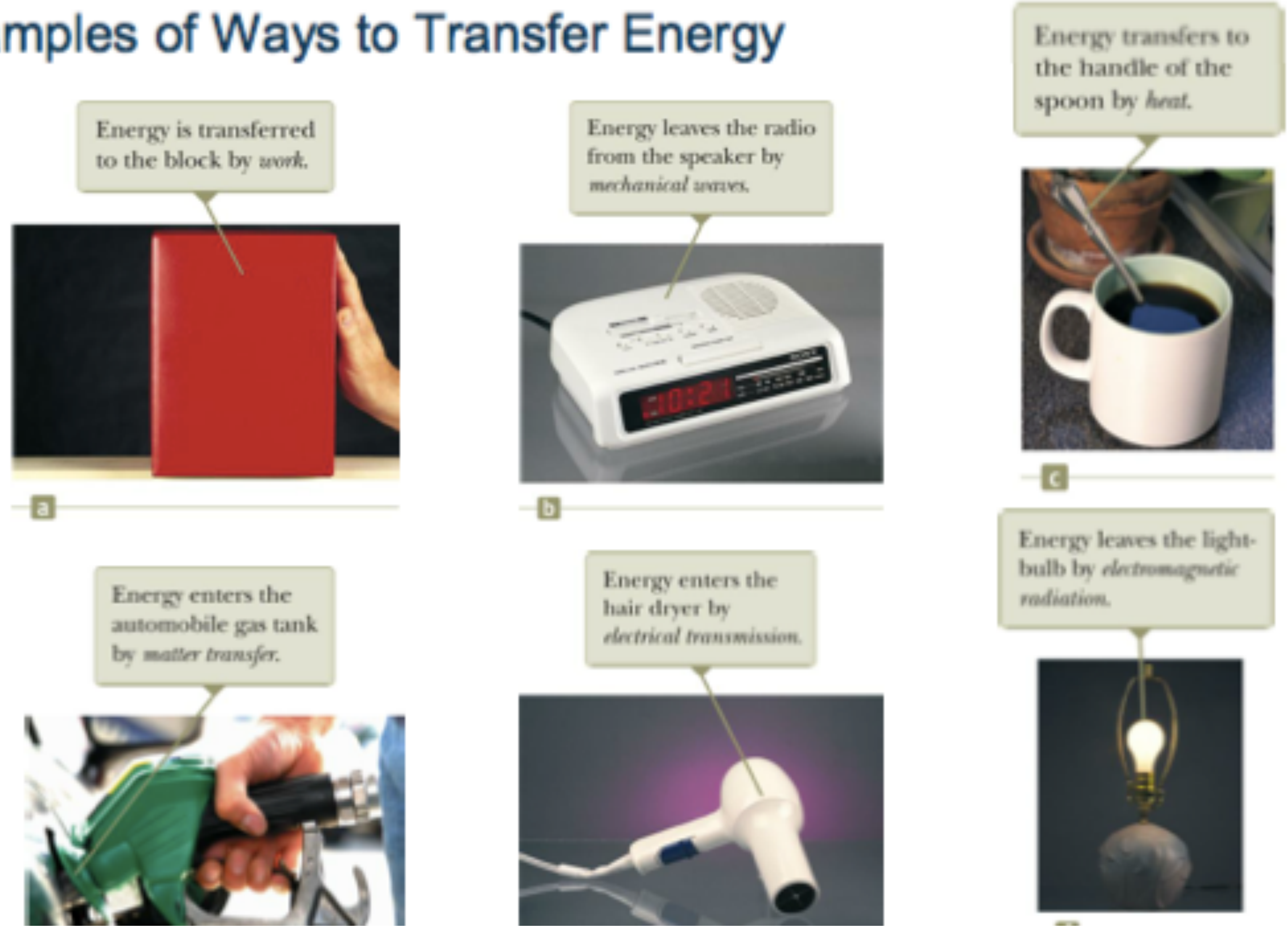
Heat – the mechanism of energy transfer that is driven by a temperature difference between two regions in space.

Matter Transfer – matter physically crosses the boundary of the system, carrying energy with it.

Electrical Transmission – energy transfer into or out of a system by electric current.

Electromagnetic Radiation – energy is transferred by electromagnetic waves.

Examples of Ways to Transfer Energy



Conservation of Energy

Energy is conserved

- This means that energy cannot be created nor destroyed.
- If the total amount of energy in a system changes, it can only be due to the fact that energy has crossed the boundary of the system by some method of energy transfer.

Isolated System

For an isolated system, $\Delta E_{mech} = 0$

- Remember $E_{mech} = K + U$
- This is ***conservation of energy*** for an isolated system with no non-conservative forces acting.

If non-conservative forces are acting, some energy is transformed into internal energy.

Conservation of Energy becomes $\Delta E_{system} = 0$

- E_{system} is all kinetic, potential, and internal energies
- This is the most general statement of the isolated system model.

Example – Ball in Free Fall

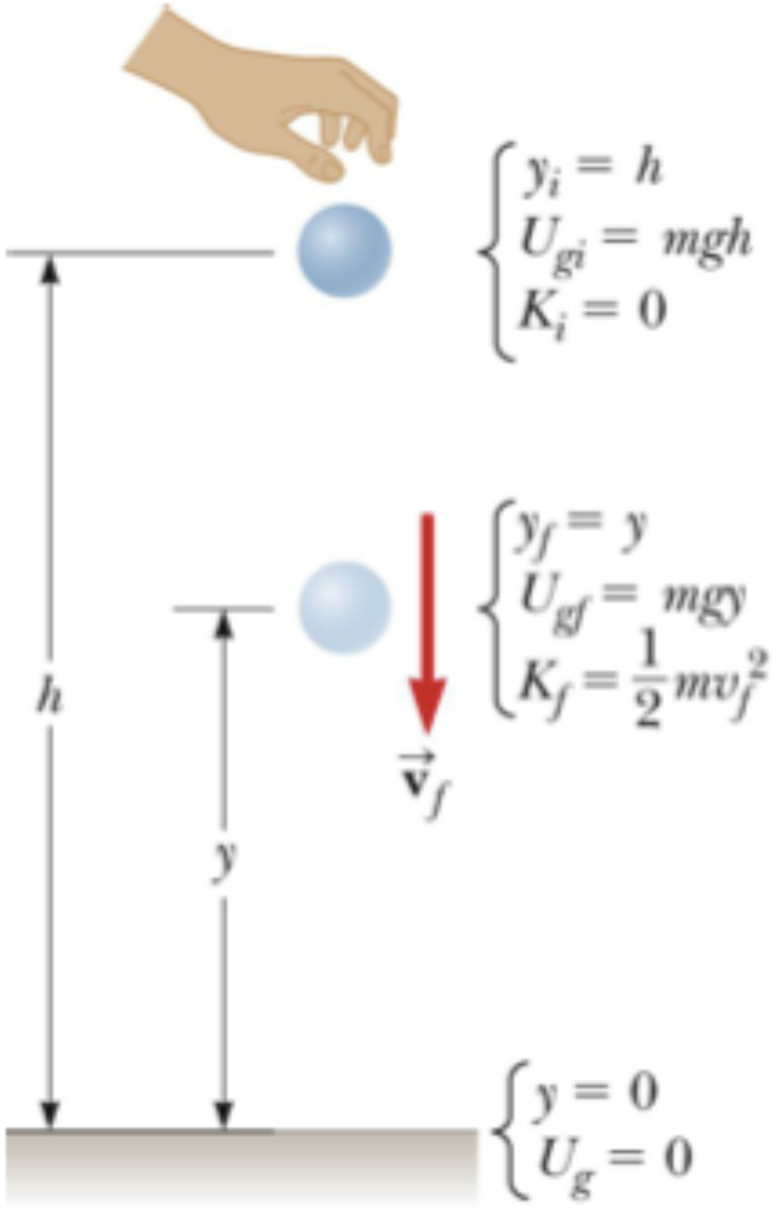
Determine the speed of the ball at a height *y* above the ground.

Conceptualize

- Use energy instead of motion

Categorize

- System is the ball and the Earth
- System is isolated
- Use the isolated system model
- Only force is gravitational which is conservative



Example – Free Fall, cont.

Analyze

- Apply the principle of Conservation of Mechanical Energy
- $K_f + U_{gf} = K_i + U_{gi}$
  - $K_i = 0$, the ball is dropped
  - Solve for v_f

$$v_f = \sqrt{2g(h-y)}$$

Finalize

- The equation for v_f is consistent with the results obtained from the particle under constant acceleration model for a falling object.

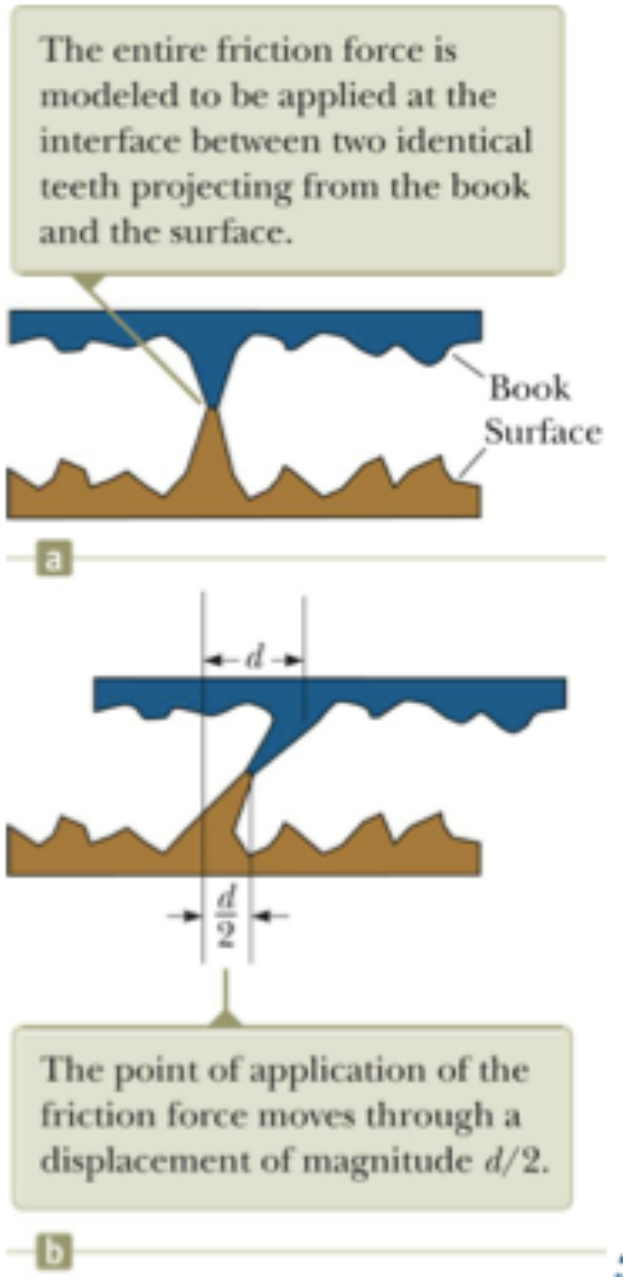
Kinetic Friction

Kinetic friction can be modeled as the interaction between identical teeth.

The frictional force is spread out over the entire contact surface.

The displacement of the point of application of the frictional force is not calculable.

Therefore, the work done by the frictional force is not calculable.



Adding Changes in Potential Energy

If friction acts within an isolated system

$$\Delta E_{mech} = \Delta K + \Delta U = -f_k\, d$$

- ΔU is the change in all forms of potential energy

If non-conservative forces act within a non-isolated system and the external influence on the system is by means of work.

$$\Delta E_{mech} = -f_k\, d + \Sigma W_{other\ forces}$$

This equation represents the non-isolated system model for a system that possesses potential energy and within which a non-conservative force acts and can be rewritten as

$$\Sigma W_{other\ forces} = W = \Delta K + \Delta U + \Delta E_{int}$$

Example – Ramp with Friction

Problem: the crate slides down the rough ramp

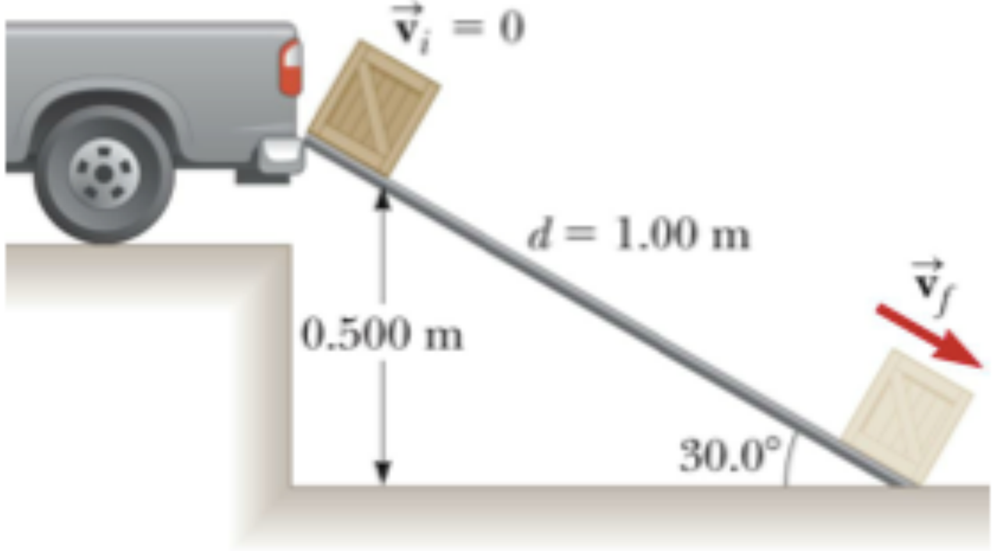
- Find speed at bottom

Conceptualize

- Energy considerations

Categorize

- Identify the crate, the surface, and the Earth as the system.
- Isolated system with non-conservative force acting



Example – Ramp, cont.

Analyze

- Let the bottom of the ramp be $y = 0$
- At the top: $E_i = K_i + U_{gi} = 0 + mgy_i$
- At the bottom: $E_f = K_f + U_{gf} = \frac{1}{2} m v_f^2 + mgy_f$
- Then $\Delta E_{mech} = E_f - E_i = -f_k d$
- Solve for v_f

Finalize

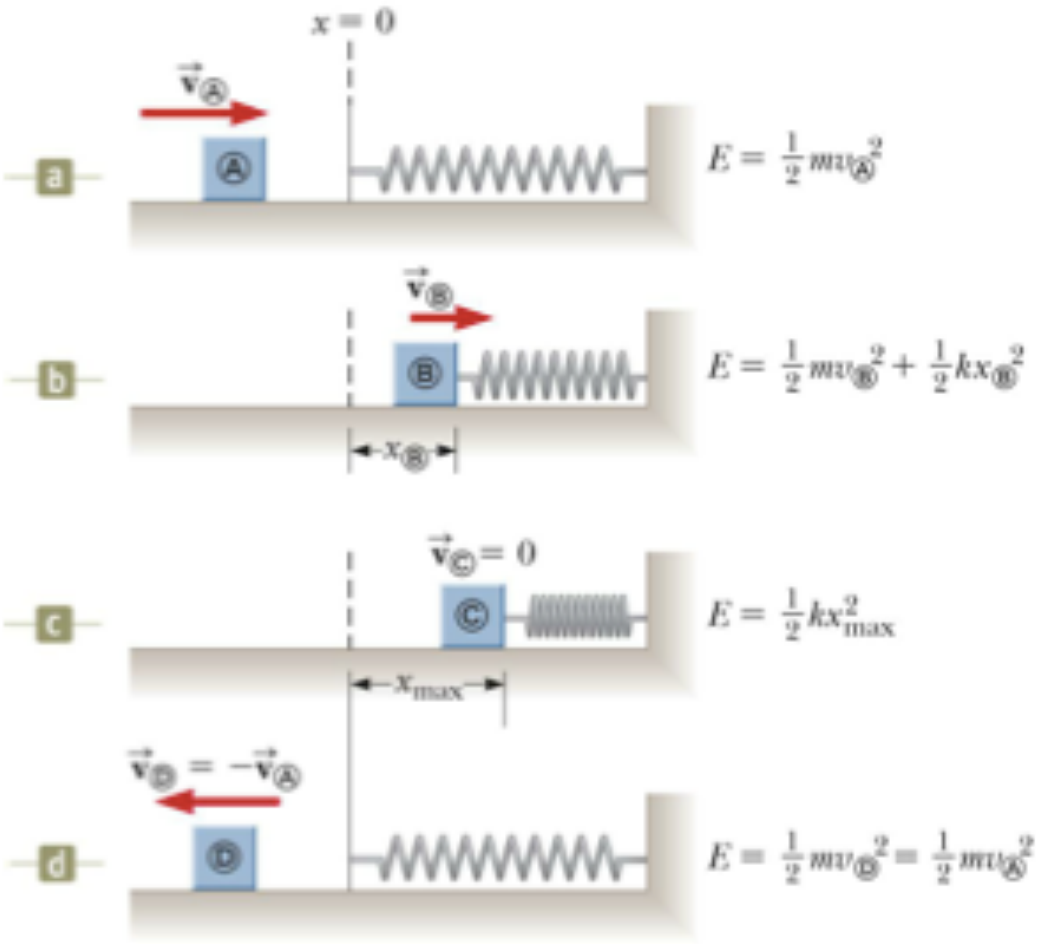
- Could compare with result if ramp was frictionless
- The internal energy of the system increased.

Example – Spring Block Collision

Without friction, the energy continues to be transformed between kinetic and elastic potential energies and the total energy remains the same.

If friction is present, the energy decreases.

- $\Delta E_{mech} = -f_k d$



Example – Spring Mass, 2

Conceptualize

- All motion takes place on a horizontal plane.
  - So no changes in gravitational potential energy

Categorize

- The system is the block and the system.
- Without friction, it is an isolated system with no non-conservative forces.

Analyze

- Before the collision, the total energy is kinetic.
- When the spring is totally compressed, the kinetic energy is zero and all the energy is elastic potential.
- Total mechanical energy is conserved

Problem – Spring Mass 3

Finalize

- Decide which root has physical meeting.

Now add friction

- Categorize
  - Now is isolated with non-conservative force
- Analyze
  - Use $\Delta E_{mech} = -f_k\, d$
  - Solve for x
- Finalize
  - The value is less than the case for no friction
    - As expected

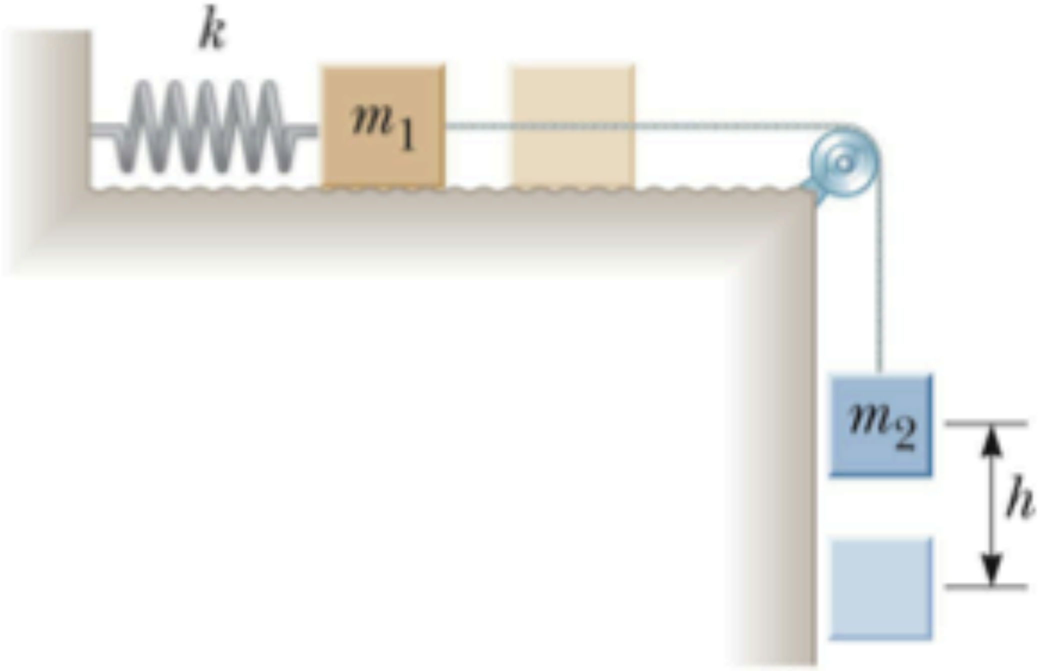
Example – Connected Blocks in Motion

Conceptualize

- Configurations of the system when at rest are good candidates for initial and final points.

Categorize

- The system consists of the two blocks, the spring, the surface, and the Earth.
- System is isolated with a non-conservative force acting
- Model the sliding block as a particle in equilibrium in the vertical direction.



Example – Blocks, cont.

Analyze

- Gravitational and elastic potential energies are involved.
  - Changes in gravitational potential energy are associated only with the falling block.
- The kinetic energy is zero if our initial and final configurations are at rest.
- The spring undergoes a change in elastic potential energy.
- The coefficient of kinetic energy can be measured.

Finalize

- This allows a method for measuring the coefficient of kinetic energy.
- Remember you can always begin with equation 8.2 and delete or expand terms as appropriate.

Power

Power is the time rate of energy transfer.

The ***instantaneous power*** is defined as

$$P \equiv \frac{dE}{dt}$$

Using work as the energy transfer method, this can also be written as

$$P_{avg} = \frac{W}{\Delta t}$$

Instantaneous Power and Average Power

The instantaneous power is the limiting value of the average power as Δt approaches zero.

$$P = \lim_{\Delta t \to 0} \frac{W}{\Delta t} = \frac{dW}{dt} = \vec{\mathbf{F}} \cdot \frac{d\vec{\mathbf{r}}}{dt} = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$$

This expression for power is valid for any means of energy transfer.

Units of Power

The SI unit of power is called the watt.

- 1 watt = 1 joule / second = 1 kg · m^2 / s^3

A unit of power in the US Customary system is horsepower.

- 1 hp = 746 W

Units of power can also be used to express units of work or energy.

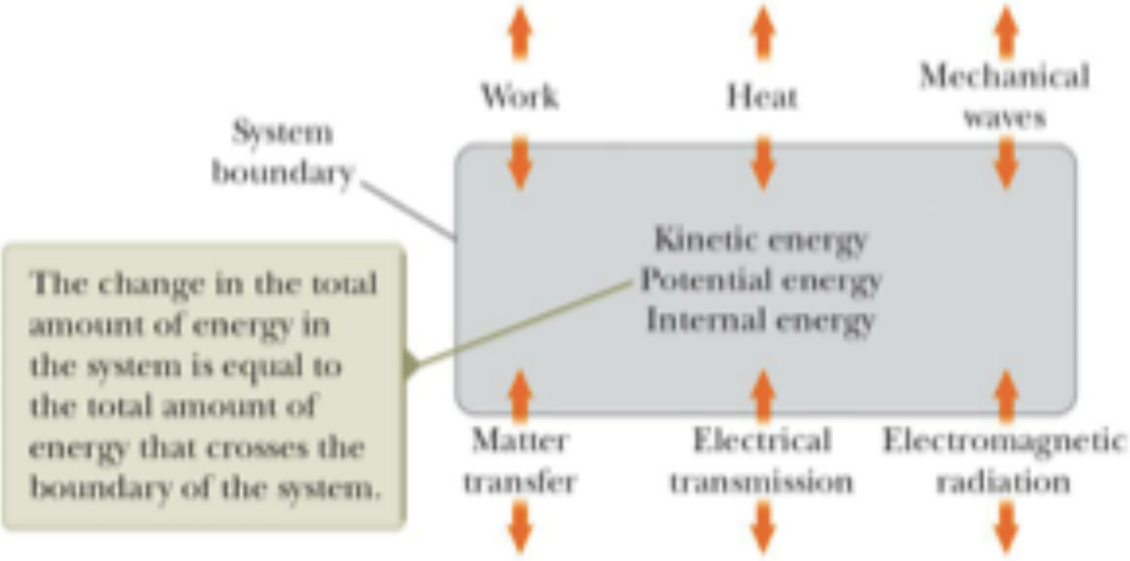
- 1 kWh = (1000 W)(3600 s) = 3.6×10^6 J

Problem Solving Summary – Non-isolated System

The most general statement describing the behavior of a non-isolated system is the conservation of energy equation.

$$\Delta E_{system} = \Sigma T$$

This equation can be expanded or have terms deleted depending upon the specific situation.



Problem Solving Summary – Isolated System

The total energy of an isolated system is conserved

$$\Delta E_{system} = 0$$

If no non-conservative forces act within the isolated system, the mechanical energy of the system is conserved.

$$\Delta E_{mech} = 0$$