Chapter 7

Energy and Power

Energy Considerations

- Energy cannot be created, nor can it be destroyed, but it can change from one form into another.
  It is essential to the study of physics and then it is applied to chemistry, biology, geology, astronomy
- In some cases it is easier to solve problems with energy then Newton's laws

Forms of Energy

- Mechanical
  - focus for now
- chemical
- electromagnetic
- Nuclear
- Heat
- Sound

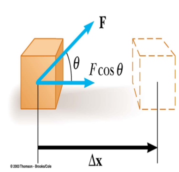
Work

- Provides a link between force and energy
- The work, *W*, done by a constant force on an object is defined as the product of the component of the force along the direction of displacement and the magnitude of the displacement

$$W \equiv (F\cos\theta)\Delta x$$

Work, cont.

- $W \equiv (F\cos\theta)\Delta x$
  - F cos θ is the component of the force in the direction of the displacement
    - Process Called the Dot Product
  - Δ x is the displacement



Units of Work

- SI
  - Newton • meter = Joule
    - N • m = J

More About Work

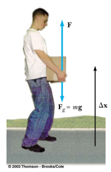
- Work gives no information about
  - the time it took for the displacement to occur
  - the velocity or acceleration of the object
- Work is a Scalar quantity
- The work done by a force is zero when the force is perpendicular to the displacement
  - cos 90° = 0
- If there are multiple forces acting on an object, the total work done is the algebraic sum of the amount of work done by each force
  - Force Addition Done in the previous chapters

More About Work, cont.

- Work can be positive or negative
  - Positive if the force and the displacement are in the same direction
  - Negative if the force and the displacement are in the opposite direction

- Work on the box is positive when lifting the box – The box gains energy

- Work on the box is negative when lowering the box – The box loses energy



When Work is Zero

- Displacement is horizontal
- Force is vertical
- cos 90° = 0

Kinetic Energy

- Energy associated with the motion of an object
- $W_{net} = F\Delta x = ma\Delta d$
- Plug in:
- For $v_f^2 = v_o^2 + 2ad$

$$a\Delta d = \frac{v_f^2 - v_o^2}{2}$$

Kinetic Energy

- You get

$$Wnet = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$$

- The quantity $\frac{1}{2}mv^2$ we call kinetic energy

Kinetic Energy

- Once again Energy associated with the motion of an object
- The equation is:

$$E_k = \frac{1}{2}mv^2$$

- The units of energy are Joules!

Work-Kinetic Energy Theorem

- When work is done by a net force on an object and the only change in the object is its speed, the work done is equal to the change in the object's kinetic energy

- $W_{net} = KE_f - KE_i = \Delta KE$
  - Speed will increase if work is positive
  - Speed will decrease if work is negative

Work and Kinetic Energy

- An object's kinetic energy can also be thought of as the amount of work the moving object could do in coming to rest
  - The moving hammer has kinetic energy and can do work on the nail

Potential Energy

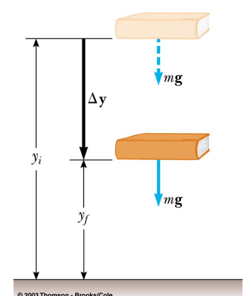
- Potential energy is associated with the position of the object within some system
  - Potential energy is a property of the system, not the object
  - A system is a collection of objects or particles interacting via forces or processes that are internal to the system

Gravitational Potential Energy

- Gravitational Potential Energy is the energy associated with the relative position of an object in space near the Earth's surface
  - Objects interact with the Earth through the gravitational force
  - Actually the potential energy of the earth-object system

Work and Gravitational Potential Energy

- PE = mgy
- Units of Potential Energy are the same as those of Work and Kinetic Energy

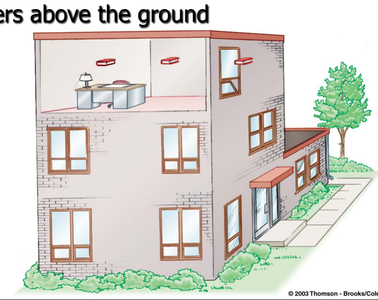


Reference Levels for Gravitational Potential Energy

- A location where the gravitational potential energy is zero must be chosen for each problem
  - The choice is arbitrary since the change in the potential energy is the important quantity
  - Choose a convenient location for the zero reference height
    - often the Earth's surface
    - may be some other point suggested by the problem

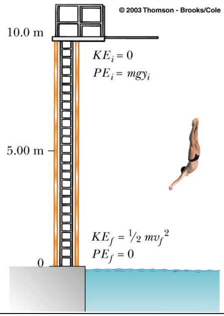
Potential Energy Example 1

- The 2kg book is .5m off the desk
- 1.25 meters above the floor
- 10 meters above the ground



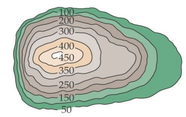
Potential Energy Example 2

- What is the Potential and Kinetic Energy of the 70kg diver at 10 m, 5m, and 0m?



Contour Lines

- A contour line is a line representing an imaginary line on the ground along which all points are at the same elevation. Therefore objects of the same mass have the same Potential energy at any point along this line.



- **Thinking of potential energy in the form of contour lines will be important when we talk about electrical potential energy.**

Power

- Is interested in the *rate* at which the energy transfer takes place
- *Power* is defined as this rate of energy transfer
  - $\overline{P} = \frac{W}{t} = F\overline{v}$
  - SI units are Watts (W)
    - $(W)att = \frac{J}{s} = \frac{\frac{kg \bullet m^2}{s^2}}{s} = \frac{kg \bullet m^2}{s^3}$

Power, cont.

- US Customary units are generally hp
  - need a conversion factor

$$1\ hp = 746\ (W)$$

  - Can define units of work or energy in terms of units of power:
    - kilowatt hours (kWh) are often used in electric bills

TABLE 5.2 **Maximum Power Output from Humans for Various Time Periods**

Power	Time
2 hp or 1 500 W	6 s
1 hp or 750 W	60 s
0.35 hp or 260 W	35 min
0.2 hp or 150 W	5 h
0.1 hp or 75 W (Safe daily level)	8 h

Fig. T5.2, p. 142

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Other Conversion Factors

- 4.18 Joule = 1 calorie
- 1 Calorie = 1000 calories

Conservation of Mechanical Energy

- Conservation in general
  - To say a "physical quantity is *conserved*" is to say that the numerical value of the quantity remains constant
- The total mechanical energy of an isolated system is conserved
- Total mechanical energy is the sum of the kinetic and potential energies in the system

$$E_i = E_f$$

$$KE_i + PE_i = KE_f + PE_f$$

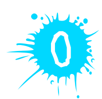
  - Other types of energy can be added to modify this equation

Problem Solving with Conservation of Energy

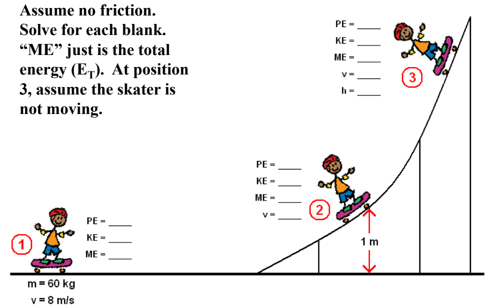
- Define the system
- Select the location of zero gravitational potential energy
  - Do *not* change this location while solving the problem
- Determine whether or not nonconservative forces are present
- If only conservative forces are present, apply conservation of energy and solve for the unknown

Energy Tables

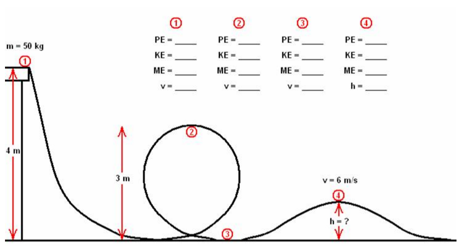
- To simplify our method of analyzing these situations, we will use an energy table. Each variable has to be found at each point.
- Remember:
  - v = 0 means **zero E_K**
  - h = 0 means **zero E_{PG}**
  - x = 0 (no spring!) means **zero E_{PE}**



Assume no friction. Solve for each blank. "ME" just is the total energy (E_T). At position 3, assume the skater is not moving.



Assume no friction. Solve for each blank. "ME" just is the total energy (E_T). Assume the car starts from rest.



- **A 30kg child slides down a water slide. What is the Childs velocity when his elevation is 2m, 1m, and 0m above the water?**

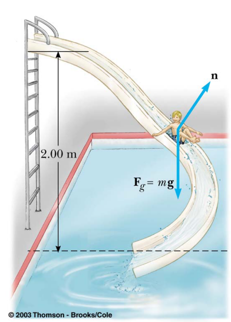


Fig. 5.24, p. 138
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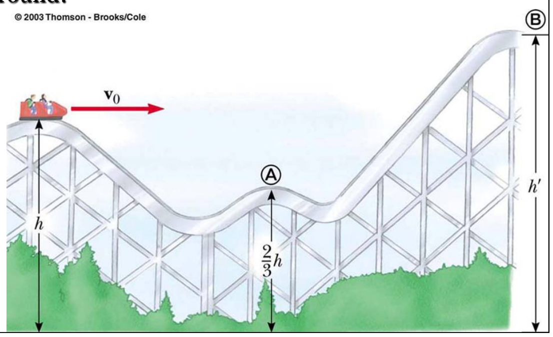
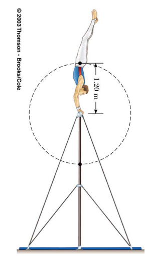
- What velocity must the rollercoaster have to get from 12 meters above the ground to 18 meters above the ground?



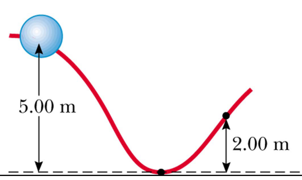
Conservation of Energy

A 65kg person's Kinetic Energy at the top is 0J. What is the persons Kinetic and Potential Energy at the bottom?



Conservation of Energy

A 7 kg ball is released from 5m. How much energy does it have at the bottom of its path? What about when it returns to 2m?



- A 65kg skier drops 10 meters. What is the skiers final velocity?

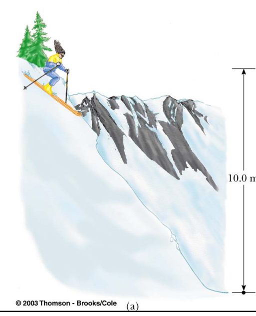


Fig. 5.13a, p. 124

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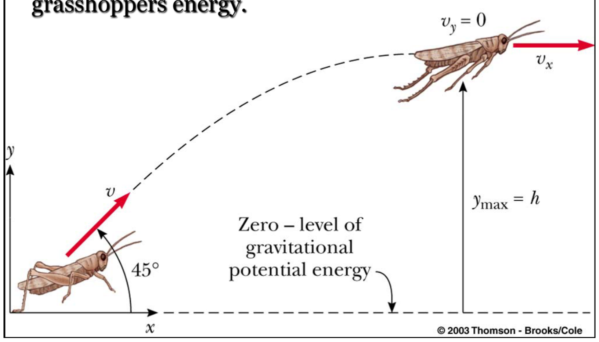
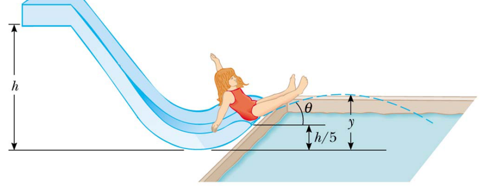
- A 2g grasshopper jumps at 10m/s at 45 degrees. How far does it jump if the air resistance uses 10% of the grasshoppers energy.



Conservation of Energy

A 30 kg slides 2 meters down a slide. At the bottom of the slide it raises again 0.4 meters (0.6 meters above the water) vertically. If the angle the girl leaves the slide is 15 degrees. How high does she go, how far horizontally does she travel?



. P5.44, p. 149

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Transferring Energy

- By Work
  - By applying a force
  - Produces a displacement of the system

- Heat
  - The process of transferring heat by collisions between molecules

Transferring Energy

- Mechanical Waves
  - a disturbance propagates through a medium
  - Examples include sound, water, seismic

- Electrical transmission
  - transfer by means of electrical current

Transferring Energy

- Electromagnetic radiation
  - any form of electromagnetic waves
    - Light, microwaves, radio waves

Notes About Conservation of Energy

- We can neither create nor destroy energy
  - Another way of saying energy is conserved
  - If the total energy of the system does not remain constant, the energy must have crossed the boundary by some mechanism
  - Applies to areas other than physics