Chapters 10 & 11: Energy

Diagram showing the flow of solar energy to power, plants, and animals through fossil fuels and food.
Power: Sources of Energy
Tidal Power

SF Bay Tidal Power Project
Main Ideas
(Encyclopedia of Physics)

Energy is an abstract quantity that an object is said to possess. It is not something you can directly observe. The usefulness of the concept comes from the Conservation of Energy. In predicting the behavior of objects, one uses the Conservation of Energy to keep track of the total energy and the transfer of energy between its various forms and between objects.

Work is the transfer of energy from one object to another by a force from one on the other that displaces the other.

Power is the rate at which energy is transferred or, the rate at which work is done. Power is the FLOW of energy.
Conservation of Energy

Energy can neither be created nor destroyed. It may change in form or be transferred from one system to another.

The total amount of energy in the Universe is constant and can never change.

\[
E_i = E_f
\]

Except for VERY brief amounts of time according to the Heisenberg Uncertainty Principle.
Ways to Transfer Energy Into or Out of A System

- **Work** – transfers by applying a force and causing a displacement of the point of application of the force

- **Mechanical Waves** – allow a disturbance to propagate through a medium

- **Heat** – is driven by a temperature difference between two regions in space
More Ways to Transfer Energy Into or Out of A System

- **Matter Transfer** – matter physically crosses the boundary of the system, carrying energy with it
- **Electrical Transmission** – transfer is by electric current
- **Electromagnetic Radiation** – energy is transferred by electromagnetic waves
Work  A force applied across a distance.

\[ W = F \Delta r \cos \theta \]

Along the direction of motion ONLY!
F must be parallel to the direction of motion!

- The sign of the work depends on the direction of \( F \) relative to \( \Delta r \)
- Work is positive when projection of \( F \) onto \( \Delta r \) is in the same direction as the displacement
- Work is negative when the projection is in the opposite direction
Work: $W = F \Delta r \cos \theta$

- Speeding up: $W > 0$

- Slowing down: $W < 0$
Units

Energy & Work are scalars and have units of the Joule:

\[ W = Fd \rightarrow N \cdot m = kg \cdot \frac{m^2}{s^2} = J \]

\[ KE = \frac{1}{2} mv^2 \rightarrow kg(\frac{m}{s})^2 = kg \cdot \frac{m^2}{s^2} = J \]

\[ PE = mgh \]
<table>
<thead>
<tr>
<th>Object/phenomenon</th>
<th>Energy in joules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big bang</td>
<td>$10^{68}$</td>
</tr>
<tr>
<td>Energy released in a supernova</td>
<td>$10^{44}$</td>
</tr>
<tr>
<td>Hydrogen fusion energy in the oceans</td>
<td>$10^{34}$</td>
</tr>
<tr>
<td>Annual U.S. energy use</td>
<td>$8 \times 10^{19}$</td>
</tr>
<tr>
<td>Large fusion bomb (9 megaton)</td>
<td>$3.8 \times 10^{16}$</td>
</tr>
<tr>
<td>1 kg hydrogen (fusion to helium)</td>
<td>$6.4 \times 10^{14}$</td>
</tr>
<tr>
<td>1 kg uranium (nuclear fission)</td>
<td>$8.0 \times 10^{13}$</td>
</tr>
<tr>
<td>Hiroshima-size fission bomb (10 kiloton)</td>
<td>$4.2 \times 10^{13}$</td>
</tr>
<tr>
<td>90,000 ton aircraft carrier at 30 knots</td>
<td>$1.1 \times 10^{10}$</td>
</tr>
<tr>
<td>1 barrel crude oil</td>
<td>$5.9 \times 10^{9}$</td>
</tr>
<tr>
<td>1 ton TNT</td>
<td>$4.2 \times 10^{9}$</td>
</tr>
<tr>
<td>1 gallon gasoline</td>
<td>$1.3 \times 10^{8}$</td>
</tr>
<tr>
<td>Daily adult food intake</td>
<td>$1.2 \times 10^{7}$</td>
</tr>
<tr>
<td>1 ton car at 90 km/h</td>
<td>$3.1 \times 10^{5}$</td>
</tr>
<tr>
<td>1 g fat (9.3 kcal)</td>
<td>$3.9 \times 10^{4}$</td>
</tr>
<tr>
<td>1 g carbohydrate (4.1 kcal)</td>
<td>$1.7 \times 10^{4}$</td>
</tr>
<tr>
<td>1 g protein (4.1 kcal)</td>
<td>$1.7 \times 10^{4}$</td>
</tr>
<tr>
<td>Baseball at 100 mph</td>
<td>$1.5 \times 10^{2}$</td>
</tr>
<tr>
<td>Mosquito ($10^{-2}$ g) at 0.5 m/s</td>
<td>$1.3 \times 10^{-6}$</td>
</tr>
<tr>
<td>Single electron in a TV tube</td>
<td>$4.0 \times 10^{-15}$</td>
</tr>
<tr>
<td>Single electron in 120 V line</td>
<td>$1.9 \times 10^{-17}$</td>
</tr>
<tr>
<td>Energy to break one DNA strand</td>
<td>$10^{-19}$</td>
</tr>
</tbody>
</table>
Kinetic Energy

The energy an object has due to its motion.

\[ KE = \frac{1}{2} m v^2 \]

**IMPORTANT!**

v is the *TOTAL* velocity and is a scalar!!!
# Kinetic Energy

## Table 7.1

<table>
<thead>
<tr>
<th>Object</th>
<th>Mass (kg)</th>
<th>Speed (m/s)</th>
<th>Kinetic Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth orbiting the Sun</td>
<td>$5.98 \times 10^{24}$</td>
<td>$2.98 \times 10^4$</td>
<td>$2.65 \times 10^{33}$</td>
</tr>
<tr>
<td>Moon orbiting the Earth</td>
<td>$7.35 \times 10^{22}$</td>
<td>$1.02 \times 10^3$</td>
<td>$3.82 \times 10^{28}$</td>
</tr>
<tr>
<td>Rocket moving at escape speed(^a)</td>
<td>500</td>
<td>$1.12 \times 10^4$</td>
<td>$3.14 \times 10^{10}$</td>
</tr>
<tr>
<td>Automobile at 65 mi/h</td>
<td>2000</td>
<td>29</td>
<td>$8.4 \times 10^5$</td>
</tr>
<tr>
<td>Running athlete</td>
<td>70</td>
<td>10</td>
<td>3500</td>
</tr>
<tr>
<td>Stone dropped from 10 m</td>
<td>1.0</td>
<td>14</td>
<td>98</td>
</tr>
<tr>
<td>Golf ball at terminal speed</td>
<td>0.046</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>Raindrop at terminal speed</td>
<td>$3.5 \times 10^{-5}$</td>
<td>9.0</td>
<td>$1.4 \times 10^{-3}$</td>
</tr>
<tr>
<td>Oxygen molecule in air</td>
<td>$5.3 \times 10^{-26}$</td>
<td>500</td>
<td>$6.6 \times 10^{-21}$</td>
</tr>
</tbody>
</table>

\(^a\) Escape speed is the minimum speed an object must reach near the Earth’s surface in order to move infinitely far away from the Earth.
Work-Energy Theorem

The net work done changes the Kinetic Energy. If the velocity is constant, then the net work is zero.

\[ W_{net} = \Delta K \]

\[ \Delta r \]

Notice:

\[ W_{net} = \Delta KE \rightarrow (\sum F) \Delta r = ma \Delta r = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \]

\[ v_f^2 = v_i^2 + 2a\Delta r \]
Work Done by a Constant Force

A force applied across a distance.

\[ W = \vec{F} \cdot \Delta \vec{r} \]
If the Force and displacement are given by vectors use Scalar Product of Two Vectors!

- The scalar product of two vectors is written as $A \cdot B$
  - It is also called the dot product

$$A \cdot B = A_x B_x + A_y B_y + A_z B_z$$

- $A \cdot B = AB \cos \theta$
  - $\theta$ is the angle between $A$ and $B$

$$\theta = \cos^{-1}(\frac{\vec{A} \cdot \vec{B}}{AB})$$

$W = F \Delta r \cos \theta$

Becomes…

$$W = \vec{F} \cdot \Delta \vec{r}$$
Constant Force Problem

If the resultant force acting on a 2.0-kg object is equal to $(3\mathbf{i} + 4\mathbf{j})$ N, what is the net work done as the object moves from $(7\mathbf{i} – 8\mathbf{j})$ m to $(11\mathbf{i} – 5\mathbf{j})$ m? If the object was initially at rest, what is the change in kinetic energy and final velocity?

a. $+36$ J  

b. $+28$ J  

c. $+32$ J  

d. $+24$ J  

e. $+60$ J
Work Done by a Varying Force

The work done is equal to the area under the curve

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

where

\[ F_x = F \cos \theta \]
Varying Force Problem

A force acting on an object moving along the x axis is given by

\[ F_x = (14x - 3.0x^2) \, \text{N} \]

where \( x \) is in m. How much work is done by this force as the object moves from \( x = -1 \, \text{m} \) to \( x = +2 \, \text{m} \)?

a. \(+12 \, \text{J}\)

b. \(+28 \, \text{J}\)

c. \(+40 \, \text{J}\)

d. \(+42 \, \text{J}\)

e. \(-28 \, \text{J}\)
The interplanetary probe is attracted to the sun by a force given by:

$$F_{12} = -\frac{1.3 \times 10^{22}}{r^2}$$

The negative sign indicates that the force is *attractive*. This is because of the way that the polar unit vectors are defined. With the origin located at the sun and the radial vector pointing towards the probe, the force of gravity acting on the probe is in the negative direction.
Work Done by a Varying Force: Gravity

The probe is moving away from the sun so the work done ON the probe BY the sun is slowing it down. Thus, the work should be negative.

\[ W = \int_{1.5 \times 10^{11}}^{2.3 \times 10^{11}} \left( -\frac{1.3 \times 10^{22}}{x^2} \right) dx \]

Attractive force versus distance for interplanetary probe. The area under the curve is negative since curve is below x-axis.

\[ F_{12} = -\frac{1.3 \times 10^{22}}{r^2} \]

\[ = -3 \times 10^{10} J \]
A certain pendulum consists of a 1.5-kg mass swinging at the end of a string (length = 2.0 m). At the lowest point in the swing the tension in the string is equal to 20 N. To what maximum height above this lowest point will the mass rise during its oscillation?

a. 77 cm  
b. 50 cm  
c. 63 cm  
d. 36 cm  
e. 95 cm
Work Done by a Varying Force

Hooke’s Law $F_s = - kx$
Hooke’s Law

*Ut tensio, sic vis* - as the extension, so is the force

Hooke’s Law describes the *elastic* response to an applied force.

Elasticity is the property of an object or material which causes it to be restored to its original shape after distortion.

An elastic system displaced from equilibrium oscillates in a simple way about its equilibrium position with *Simple Harmonic Motion.*
Elastic Systems  \[ F = -kx \]

Small Vibrations
Robert Hooke (1635-1703)

• Leading figure in Scientific Revolution
• Contemporary and arch enemy of Newton
• Hooke’s Law of elasticity
• Worked in Physics, Biology, Meteorology, Paleontology
• Devised compound microscope
• Coined the term “cell”
Hooke’s Law \( F_s = -kx \)

The Restoring Force

- When \( x \) is positive (spring is stretched), \( F \) is negative

- When \( x \) is 0 (at the equilibrium position), \( F \) is 0

- When \( x \) is negative (spring is compressed), \( F \) is positive
Hooke’s Law

It takes twice as much force to stretch a spring twice as far. The linear dependence of displacement upon stretching force:

\[ F_{\text{applied}} = kx \]
Hooke’s Law

*Stress is directly proportional to strain.*

\[ F_{\text{applied}} (\text{stress}) = kx(\text{strain}) \]
Spring Constant $k$: Stiffness

- The larger $k$, the stiffer the spring
- Shorter springs are stiffer springs
- $k$ strength is inversely proportional to the number of coils
Spring Question

Each spring is identical with the same spring constant, k. Each box is displaced by the same amount and released. Which box, if either, experiences the greater net force?
Work Done by a Spring

- Identify the block as the system
- The work is the area under the
- Calculate the work as the block moves from $x_i = -x_{\text{max}}$ to $x_f = 0$

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

- The total work done as the block moves from $-x_{\text{max}}$ to $x_{\text{max}}$ is zero.
Energy in a Spring

What speed will a 25g ball be shot out of a toy gun if the spring (spring constant = 50.0N/m) is compressed 0.15m? Ignore friction and the mass of the spring.

Use Energy!

\[ W_{spring} = \Delta KE_{ball} \]

\[ \frac{1}{2} kx^2 = \frac{1}{2} mv^2 \]

\[ v = \sqrt{\frac{k}{m}}x \]

\[ v = \sqrt{\frac{50.0N/m}{.025kg}} (.15m) = 6.7m/s \]
Work done by a Spring

The horizontal surface on which the block slides is frictionless. The speed of the block before it touches the spring is 6.0 m/s. How fast is the block moving at the instant the spring has been compressed 15 cm? $k = 2.0 \text{ kN/m}$ The mass of the block is 2.0 kg.

a. 3.7 m/s
b. 4.4 m/s
c. 4.9 m/s
d. 5.4 m/s
e. 14 m/s

\[ W_{net} = \Delta K \]
Nonconservative Forces

A 1.5-kg block sliding on a rough horizontal surface is attached to one end of a horizontal spring \((k = 200 \text{ N/m})\) which has its other end fixed. If this system is displaced 20 cm horizontally from the equilibrium position and released from rest, the block first reaches the equilibrium position with a speed of 2.0 m/s. What is the coefficient of kinetic friction between the block and the horizontal surface on which it slides?

a. 0.34  
b. 0.24  
c. 0.13  
d. 0.44  
e. 0.17
A 12-kg projectile is launched with an initial vertical speed of 20 m/s. It rises to a maximum height of 18 m above the launch point. How much work is done by the dissipative (air) resistive force on the projectile during this ascent?

a. $-0.64 \text{ kJ}$
b. $-0.40 \text{ kJ}$
c. $-0.52 \text{ kJ}$
d. $-0.28 \text{ kJ}$
e. $-0.76 \text{ kJ}$
Energy States

Left to their own devices, systems always seek out the lowest energy state available to them. Systems want to be at rest or in a constant state of motion.

You have to do work on the Rock to roll it back up the hill. This will give the Rock Energy – the potential of rolling back down – Potential Energy.
Potential Energy

The energy an object has due to its position in a force field. For example: gravity or electricity. The Potential Energy is relative to a ‘ground’ that is defined.

(Potential Energy: $U$ or $PE$)
Gravitational Potential Energy

\[ PE = mgh \]

It takes work to move the object and that gives it energy!

Same change in height!

\[ PE = mgh \]

The “ground”: \( h = 0 \)

IMPORTANT!
Either path gives the same potential energy!
WHY?
Work Up an Incline

The block of ice weighs 500 Newtons. How much work does it take to push it up the incline compared to lifting it straight up? Ignore friction.
Work Up an Incline

Work = Force x Distance

Straight up: \[ W = Fd = 500N \cdot 3m = 1500J \]

Push up: \[ F = mg \sin \theta = 500N \cdot \frac{3}{6} = 250N \]
\[ W = Fd = 250N \cdot 6m = 1500J \]

What is the PE at the top? 1500J

An incline is a simple machine!

mg = 500N
Simple Machines

Force Multipliers

Same Work, Different Force, Different Distance

\[ F d = F_d \]

\[ 50 \times 25 = 5000 \times 0.25 \]
Conservative Forces and Potential Energy

• Define a potential energy function, $U$, such that the work done by a conservative force equals the decrease in the potential energy of the system.

• The work done by such a force, $F$, is

$$W_C = \int_{x_i}^{x_f} F_x \, dx = -\Delta U$$

• For an infinitessimal displacement:

$$F_x = -\frac{dU}{dx}$$
Energy Diagrams and Stable Equilibrium: Mass on a Spring

- The $x = 0$ position is one of **stable equilibrium**
- Configurations of stable equilibrium correspond to those for which $U(x)$ is a minimum.
- $x = x_{\text{max}}$ and $x = -x_{\text{max}}$ are called the turning points
Energy Diagrams and Unstable Equilibrium

- $F_x = 0$ at $x = 0$, so the particle is in equilibrium.
- For any other value of $x$, the particle moves away from the equilibrium position.
- This is an example of unstable equilibrium.
- Configurations of unstable equilibrium correspond to those for which $U(x)$ is a maximum. Ex: A pencil standing on its end.

\[
F_x = -\frac{dU}{dx}
\]
Total Mechanical Energy

The total mechanical energy of a system is defined as the sum of the kinetic and potential energies:

\[ E_{\text{mech}} = K + U \]

If only conservative forces act, the total mechanical energy is conserved.

\[ K_f + U_f = K_i + U_i \]

\[ \Delta U + \Delta K = 0 \]
Work Done by a Conservative Force

Conservative forces do work on a system such that Energy is exactly transferred between kinetic energy and potential energy, there is no energy transferred (lost) to friction or heat. Thus Conservation of Mechanical Energy gives:

\[
E_i = E_f
\]

\[
K_i + U_i = K_f + U_f
\]

\[
-(U_f - U_i) = K_f - K_i
\]

\[
-\Delta U = \Delta K
\]

By the Work-Energy Theorem: \[W_c = \Delta K\]

The work done by a conservative force: \[W_c = \Delta K = -\Delta U\]
Conservation of Energy

Energy can neither be created nor destroyed. It may change in form or be transferred from one system to another.

The total amount of energy in the Universe is constant and can never change.

\[ E_i = E_f \]

Except for VERY brief amounts of time according to the Heisenberg Uncertainty Principle.
Conservation of Mechanical Energy

If there are no frictional forces, PE is converted into KE.

- PE = 10,000
  KE = 0
  Total Energy: 10,000J

- PE = 7500
  KE = 2500
  Total Energy: 10,000J

- PE = 5000
  KE = 5000
  Total Energy: 10,000J

- PE = 2500
  KE = 7500
  Total Energy: 10,000J

- PE = 0
  KE = 10,000
  Total Energy: 10,000J
Conservative Force of Gravity

Frictionless Ramp

\[ E_i = E_f \]

\[ KE_i + PE_i = KE_f + PE_f \]
Conservation of Mechanical Energy

Potential Energy of a Spring

(a) $v_A$

Potential

$E = \frac{1}{2} m v_A^2$

(b) $v_B$

Kinetic & Potential

$E = \frac{1}{2} m v_B^2 + \frac{1}{2} k x_B^2$

(c) $v_C = 0$

Potential

$E = \frac{1}{2} k x_{max}^2$

(d) $v_D = -v_A$

Kinetic

$E = \frac{1}{2} m v_D^2 = \frac{1}{2} m v_A^2$

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Ski Hill Problem

If the skier has an initial velocity of 12m/s, what is his final velocity at the top of the ramp? Ignore Friction.

\[ v_i = 12 \text{ m/s} \]

\[ v_f = ? \]

\[ \text{KE}_i \]

\[ 2.5 \text{ m} \]

\[ 35^\circ \]
Ski Hill Problem

Take the ground to be the ground: $U = 0$.

\[
K_i + U_i = K_f + U_f
\]

\[
\frac{1}{2} m v_i^2 + 0 = \frac{1}{2} m v_f^2 + mgh
\]

\[
v_f = \sqrt{v_i^2 - 2gh}
\]

$v_f = 9.75 \text{ m/s}$

$v_i = 12 \text{ m/s}$

$\text{KE}_i$

$\text{PE}=0$
Nonconservative Forces

Nonconservative forces do work on a system such that Mechanical Energy is ‘lost’ or transformed into internal energy (heat) or can’t be directly transformed back into KE or PE. Conservation of Energy gives:

\[ E_i = E_f \]

\[ K_i + U_i = K_f + U_f - W_{nc} \]

Examples: Air resistance, Friction, Applied Forces

\( (ex: W_f = -f \cdot \Delta r) \)
Nonconservative Forces

The change in mechanical energy of a system is due to the nonconservative forces acting on it.

\[ E_i = E_f \]

\[ K_i + U_i = K_f + U_f - W_{nc} \]

\[ \Delta U + \Delta K = W_{nc} \]

Ex: Change in energy bank spent on friction:

\[ \Delta U + \Delta K = -fd \]
If the skier has an initial velocity of 12 m/s, what is his final velocity at the top of the ramp? The coefficient of kinetic friction between the skies and the hill is 0.13. The mass of the skier is 80 kg.
Ski Hill Problem

\[ K_i + U_i = K_f + U_f - W_f \]

\[ \frac{1}{2} m v_i^2 + 0 = \frac{1}{2} m v_f^2 + mgh + fd \]

\[ v_f = \sqrt{v_i^2 - 2gh - 2fd/m} \]

What is \( f \) and \( d \)?
Ski Hill Problem

\[ v_f = \sqrt{v_i^2 - 2gh - 2fd/m} \]

\[ f = \mu mg \cos \theta, \quad d = h / \sin \theta \]

\[ v_f = \sqrt{v_i^2 - 2gh - \mu 2g \cos \theta (h / \sin \theta)} \]

\[ v_f = \sqrt{v_i^2 - 2gh(1 + \mu \cot \theta)} \]

\[ v_f = 9.27 \text{m/s} \quad (< 9.75 \text{m/s}) \]

Does not depend on the mass of the skier!!
A certain pendulum consists of a 1.5-kg mass swinging at the end of a string (length = 2.0 m). At the lowest point in the swing the tension in the string is equal to 20 N. To what maximum height above this lowest point will the mass rise during its oscillation?

a. 77 cm
b. 50 cm
c. 63 cm
d. 36 cm
e. 95 cm
Nonconservative Forces
System of Objects

Change in energy bank due to NC forces!!

\[ W_{nc} = \Delta U_1 + \Delta U_2 + \Delta K_1 + \Delta K_2 \]

\[ \mu \neq 0 \]
A 20.0-kg block is connected to a 30.0-kg block by a string that passes over a light frictionless pulley. The 30.0-kg block is connected to a spring that has negligible mass and a force constant of 250 N/m. The spring is unstretched when the system is as shown in the figure, and the incline is frictionless. The 20.0-kg block is pulled 20.0 cm down the incline (so that the 30.0-kg block is 40.0 cm above the floor) and released from rest. Find the speed of each block when the 30.0-kg block is 20.0 cm above the floor (that is, when the spring is unstretched.)

Take the equilibrium position shown as the ground for the m2. Take the initial position the ground for m1. The blocks will have the same final speed.

\[
(K_i + U_{gi})_1 + (K_i + U_{gi} + U_{si})_2 = (K_f + U_{fg})_1 + (K_f + U_{gf} + U_{sf})_2
\]

Energy Bank:

\[
(U_{gi} + U_{si})_2 = (K_f + U_{fg})_1 + K_{2f}
\]

:Expenditures

\[
m_2gx + \frac{1}{2}kx^2 = \frac{1}{2}(m_1 + m_2)v^2 + m_1gx \sin \theta
\]

\[
v = \sqrt{\frac{2gx(m_2 - m_1 \sin \theta) + kx^2}{m_1 + m_2}}
\]

\[
v = 1.24 \text{ m/s}
\]
A 2.00-kg block situated on a rough incline is connected to a spring of negligible mass having a spring constant of 100 N/m. The pulley is frictionless. The block is released from rest when the spring is unstretched. The block moves 20.0 cm down the incline before coming to rest. Find the coefficient of kinetic friction between block and incline. The picture shows the final state. Take it to be the ground where $U=0$.

The gain in internal energy due to friction represents a loss in mechanical energy that must be equal to the change in the kinetic energy plus the change in the potential energy.

$$\Delta U_g + \Delta U_s + \Delta K = W_{nc}$$

$$-mgh + \frac{1}{2}kd^2 + 0 = -fd$$

$$-mgd \sin \theta + \frac{1}{2}kd^2 = -\mu mg \cos \theta \cdot d$$

$$\mu = \frac{\frac{1}{2}kd^2 - mgd \sin \theta}{mg \cos \theta \cdot d} \rightarrow \mu = \tan \theta - \frac{kd}{2mg \cos \theta}$$

$\mu = .115$
P8.65 Jane, whose mass is 50.0 kg, needs to swing across a river (having width $D$) filled with man-eating crocodiles to save Tarzan from danger. She must swing into a wind exerting constant horizontal force $F$, on a vine having length $L$ and initially making an angle $\theta$ with the vertical (Fig. P8.65). Taking $D = 50.0\,\text{m}$, $F = 110\,\text{N}$, $L = 40.0\,\text{m}$, and $\theta = 50.0^\circ$, (a) with what minimum speed must Jane begin her swing in order to just make it to the other side? (b) Once the rescue is complete, Tarzan and Jane must swing back across the river. With what minimum speed must they begin their swing? Assume that Tarzan has a mass of 80.0 kg.
Energy or Newton’s 2nd Law?

P8.63. A child slides without friction from a height $h$ along a curved water slide (Fig. P8.63). She is launched from a height $h/5$ into the pool. Determine her maximum airborne height $y$ in terms of $h$ and $\theta$. 

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