Energy
Work vs Potential Energy
Energy and Friction

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Last time

- comment about conservation laws
- work vs. potential energy (nonisolated vs. isolated system models)
- energy conservation in isolated systems

Overview

- energy conservation in isolated systems
- kinetic friction and energy

How to Solve Energy Conservation Problems

1. Draw (a) diagram(s). Free body diagrams or full pictures, as needed.
2. Identify the system. State what it is. Is it isolated?
3. Identify the initial point / configuration of the system.
4. Identify the final point / configuration of the system.
5. Write the energy conservation equation.
6. Fill in the expressions as needed.
7. Solve.
8. (Analyze answer: reasonable value?, check units, etc.)

Isolated system example

Page 237, #7

7. **M** Two objects are connected by a light string passing over a light, frictionless pulley as shown in Figure P8.7. The object of mass $m_1 = 5.00$ kg is released from rest at a height $h = 4.00$ m above the table. Using the isolated system model, (a) determine the speed of the object of mass $m_2 = 3.00$ kg just as the 5.00-kg object hits the table and (b) find the maximum height above the table to which the 3.00-kg object rises.

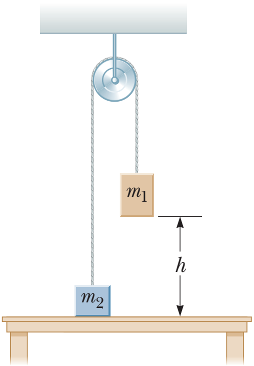

Figure P8.7
Problems 7 and 8.

Isolated system example

(a) find speed of m_2 as m_1 hits table

System: blocks + Earth, isolated.

Initial point, ⓘ: m_2 is in contact with the table,

Final point, ⓕ: m_1 is just about to hit the table.

Let's choose the table surface to be $y = 0$, $U = 0$

$$\cancelto{0}{W} = \Delta K + \Delta U$$

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$$
\begin{aligned}
\cancelto{0}{W} &= \Delta K + \Delta U \\
0 &= (K_f - \cancelto{0}{K_i}) + (U_{g,f} - U_{g,i}) \\
0 &= \frac{1}{2}(m_1 + m_2)v^2 + (m_1 gh - m_2 gh) \\
v &= \sqrt{\frac{2(m_1 - m_2)gh}{(m_1 + m_2)}} \\
v &= \underline{4.43 \text{ m/s}}
\end{aligned}
$$

Isolated system example

(b) find max height above table of m_2

System: **block 2** + Earth, isolated.

Initial point, ⓘ: m_2 at height h, m_1 is in contact with the table

Final point, ⓕ: m_2 at max height.

Let the table surface to be $y = 0$, $U = 0$

$$\cancelto{0}{W} = \Delta K + \Delta U$$

Isolated system example

(b) find max height above table of m_2

System: **block 2** + Earth, isolated.

Initial point, ⓘ: m_2 at height h, m_1 is in contact with the table

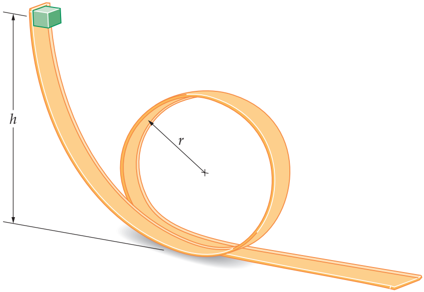
Final point, ⓕ: m_2 at max height.

Let the table surface to be $y = 0$, $U = 0$

$$\begin{aligned}
\cancel{W}^{\,0} &= \Delta K + \Delta U \\
0 &= (\cancel{K_f}^{\,0} - K_i) + (U_{g,f} - U_{g,i}) \\
0 &= -\frac{1}{2} m_2 v^2 + (m_2 g h_{\text{max}} - m_2 g h) \\
h_{\text{max}} &= h + \frac{v^2}{2g} \\
h_{\text{max}} &= \underline{5.00\ \text{m}}
\end{aligned}$$

Example: Energy and Motion in a Circle

A block of mass m slides from rest on a frictionless loop-the-loop track, as shown. What is the minimum release height, h, required for the block to maintain contact with the track at all times? Give your answer in terms of the radius of the loop, r.



[1]Walker, "Physics", Ch 8, prob 96.

Example: Energy and Motion in a Circle

Under what condition would the block fall off the track before completing the loop?

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When the block falls, the normal force on it from the track goes to zero.

If the block is on the verge of being able to make it around, the place it would just start to fall is the top of the loop. At the top of the loop:

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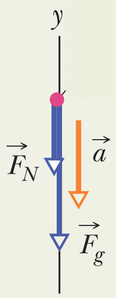
System: block



y-direction:

$$
\begin{aligned}
F_{\text{net},y} &= ma_y \\
-N - F_g &= m(-a) \\
-\overset{0}{\cancel{N}} - mg &= -\frac{mv_{\min}^2}{r} \\
v_{\min} &= \sqrt{rg}
\end{aligned}
$$

Example: Energy and Motion in a Circle

System: block + Earth, isolated.

Initial point, ⓘ: m at height h,

Final point, ⓕ: m at top of circle.

Choose the table bottom of the track to be $y = 0$, $U = 0$

$$\cancelto{0}{W} = \Delta K + \Delta U$$

Example: Energy and Motion in a Circle

System: block + Earth, isolated.

Initial point, i: m at height h,

Final point, f: m at top of circle.

Choose the table bottom of the track to be $y = 0$, $U = 0$

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\begin{aligned}
\cancelto{0}{W} &= \Delta K + \Delta U \\
0 &= (K_f - \cancelto{0}{K_i}) + (U_{g,f} - U_{g,i}) \\
0 &= \frac{1}{2} m v_{\text{min}}^2 + (mg(2r) - mgh) \\
h &= 2r + \frac{r}{2} \\
h &= \underline{\frac{5r}{2}}
\end{aligned}
$$

Tracking Energy in a System, now with Internal Energy

In general we can express the conservation of energy for our system as:

$$W = \Delta K + \Delta U + \Delta E_{\text{int}}$$

where

- W is the net work done by all *external forces* on the system
- ΔK is the change in kinetic energy of the system
- ΔU is the change in potential energy of the system
- ΔE_{int} is the change in *internal energy* of the system

Tracking Energy in a System

$$W = \Delta K + \Delta U + \Delta E_{\text{int}}$$

where

- W covers **energy transfers** into or out of the system
- ΔK is the **change in motion** of parts of the system
- ΔU is the **change configuration** of the system
- ΔE_{int} is energy converted to **heating effects from friction** in the system (or other non-conservative effects)

Internal Energy and Kinetic Friction

When ΔE_{int} is energy converted to **heating effects from friction** in the system only:

$$\Delta E_{\text{int}} = f_k s$$

where f_k is the magnitude of the friction force and s is the total path length that the object travels with this friction force acting.

The longer the path, the larger s, the larger ΔE_{int}.

Kinetic Friction

Just as we had two choices for how treat a conservative force acting on our system (depending on what we call our system) we have two choices for how to think of the effect of friction.

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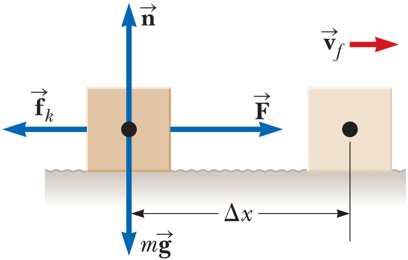
Consider block sliding on a surface.



Kinetic Friction: Two Views

View 1 (textbook's approach)

System: block (mass) + internal degrees of freedom of the block and the surface

By "internal degrees of freedom" we mean all of the ways energy could be stored in the molecules making up the block; molecular vibrations, etc.

$$W_{\text{net,ext}} = \Delta K + \Delta E_{\text{int}}$$

Kinetic Friction: Two Views

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By "internal degrees of freedom" we mean all of the ways energy could be stored in the molecules making up the block; molecular vibrations, etc.

$$\begin{aligned} W_{\text{net,ext}} &= \Delta K + \Delta E_{\text{int}} \\ W_{\text{app}} &= \Delta K + f_k s \\ W_{\text{app}} - f_k s &= \Delta K \end{aligned}$$

Kinetic Friction: Two Views

View 2:

System: block (as a point mass)

The "internal" degrees of freedom are part of the environment.

$$W_{\text{net,ext}} = \Delta K$$

Kinetic Friction: Two Views

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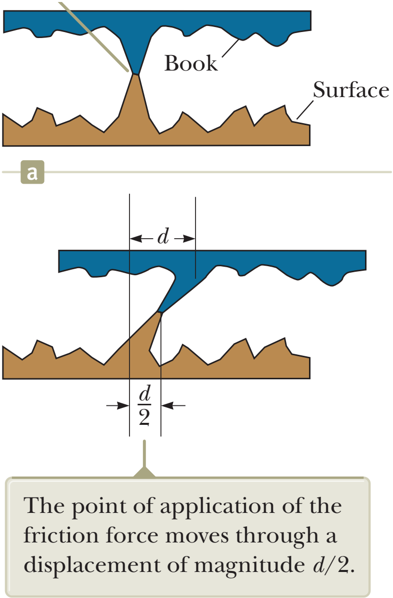
System: block (as a point mass)

The "internal" degrees of freedom are part of the environment.

$$
\begin{aligned}
W_{\text{net,ext}} &= \Delta K \\
W_{\text{app}} + W_{f_s} &= \Delta K \\
W_{\text{app}} - f_k s &= \Delta K \qquad \text{(same as view 1)}
\end{aligned}
$$

Kinetic Friction

The textbook does not ever refer to W_{f_k}.



Summary

- energy conservation in isolated systems
- kinetic friction and energy

Next Test (Friday, Feb 28 OR Mon, Mar 2)..

(Uncollected) Homework

Serway & Jewett,

- prev: Ch 8, onward from page 236. Probs: 5, 9, 11, 45, 59, 64[1], 65
- new: Ch 8. Probs: 13, 15, 17, 21, 23 (friction)

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[1] Ans: $v = 1.24$ m/s