FRICTION & ENERGY DISSIPATION — DAY 10

Opener Demo: Magnet Drop — "Missing Joules"

We drop the **same magnet** from the **same height** through two tubes and measure its **exit speed**.

Tube A (control): plastic (non-conducting)

Tube B (mystery): copper (conducting)

> **Prediction:** Which tube gives the **smaller** exit speed? Why would that happen if "energy is conserved"?

Tube	Drop height h (m)	Exit speed v (m/s)	Exit $K = \frac{1}{2}mv^2$ (J)	"Missing" $mgh - K$ (J)
Plastic				
Copper				

Which tube has more "missing" energy? _____ **Where did it go?** _____

THE PROBLEM WITH "ENERGY IS LOST"

THE FRICTION BUCKET

What really happens:

Friction converts organized mechanical energy (motion, height) into **disorganized thermal energy**:

- Molecules vibrate faster
- Surfaces warm up
- Energy spreads out randomly

The "bucket" model:

Think of thermal energy as a bucket that friction fills:

- Energy flows OUT of K and U
- Energy flows INTO E_{th}
- Total energy stays constant

$K + U + E_{th}$ = constant

WORK DONE BY FRICTION

THE EQUATION

Kinetic friction f_k opposes the sliding. If an object slides distance d over a surface:

$$W_{friction} = -f_k \cdot d$$

Negative here because when an object slides over a surface, the friction force on it points opposite its motion ($\theta = 180^\circ$).

Where it goes: The energy removed from the mechanical system becomes thermal energy:

$$\Delta E_{th} = f_k \cdot d$$

Note: ΔE_{th} is positive (thermal energy increases).

QUICK **Sign Check**

A box slides 3.0 m across a floor. Kinetic friction is 8.0 N.

$W_{friction} =$ _____ J $\Delta E_{th} =$ _____ J

THE GENERAL CONSERVATION EQUATION

ENERGY BOOKKEEPING

For a closed system (no external pushes), total energy is conserved:

$$K_i + U_{g,i} + U_{s,i} = K_f + U_{g,f} + U_{s,f} + \Delta E_{th}$$

Initial mechanical energy = Final mechanical energy + Energy lost to thermal

Or equivalently:

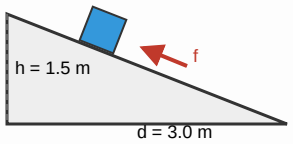
$$\Delta K + \Delta U_g + \Delta U_s + \Delta E_{th} = 0$$

Changes in all energy types must sum to zero.

Strategy update: When friction is present, add $\Delta E_{th} = f_k d$ to the right side of your energy equation. This accounts for energy leaving the mechanical system.

WE DO **Rough Ramp**

A 4.0 kg block slides down a 3.0 m ramp (height drop = 1.5 m). Friction force is 6.0 N. Find the speed at the bottom.



Given: m = 4.0 kg, h = 1.5 m, d = 3.0 m, f = 6.0 N

Step 1: Find ΔE_{th}

Step 2: Write energy equation

Step 3: Solve for v

Answer: $v =$ _____ m/s

Compare to frictionless: $v = \sqrt{2gh} = \sqrt{2(9.8)(1.5)} = 5.4$ m/s. Your answer should be less.

PRACTICE WITH FRICTION

YOU DO Sliding to a Stop

A 1500 kg car traveling at 20 m/s brakes and skids to a stop over 25 m.

a. How much kinetic energy did the car lose?

b. How much thermal energy was generated?

c. What was the friction force?

(a) $\Delta K =$ _____ J (b) $\Delta E_{th} =$ _____ J (c) $f =$ _____ N

YOU DO Spring Launch with Friction

A spring ($k = 500$ N/m) is compressed 0.20 m and launches a 0.80 kg block across a rough floor. The block travels 1.5 m before stopping. Find the friction force.

Initial energy (spring):

Final energy:

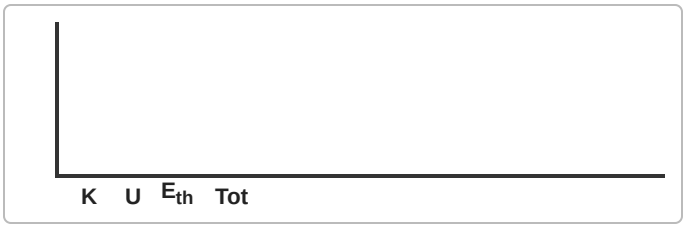
Energy equation and solve:

Answer: $f =$ _____ N

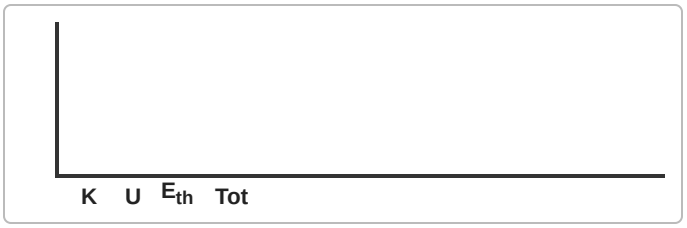
DRAW Energy Bars with Friction

A block slides down a rough ramp and comes to rest at the bottom. Draw bars at start and end.

Start (top, at rest)



End (bottom, stopped)



Key observation: Total bar height stays _____, but energy shifts from _____ to _____.

HOMEWORK

1 Quick Check

A 5.0 kg box slides 4.0 m down a rough ramp (height = 2.0 m). It reaches the bottom moving at 5.0 m/s.

(a) Initial gravitational PE: _____ J (b) Final kinetic energy: _____ J (c) Energy lost to thermal: _____ J

2 Conceptual

Two identical blocks slide down from the same height. Block A is on a frictionless ramp. Block B is on a rough ramp.

(a) Which reaches the bottom with more speed? _____ (b) Which has more total energy at the bottom? _____

(c) Explain the difference between (a) and (b).

3 Calculation

A 2.0 kg block slides down a 5.0 m ramp (height = 3.0 m) with friction force 4.0 N. Find the speed at the bottom.

Answer: $v =$ _____ m/s

4 Working Backward

A spring ($k = 800$ N/m) launches a 0.50 kg block up a rough ramp. The spring was compressed 0.15 m. The block rises only 1.2 m before stopping (less than expected).

(a) Energy stored in spring: _____ J (b) Gravitational PE gained: _____ J (c) Energy to thermal: _____ J