Phys 100 2023

Lecture 21

Weds: HW by 5pm
Read

Energy conservation

We have seen that, for objects moving under the influence of gravity and springs

$$\text{Total Energy} = KE + PE + E_{elastic}$$

remains constant throughout the object's motion. This is an example of energy conservation. We can apply this to macroscopic (large scale) systems and also microscopic systems.

DEMO: Chem Tube 3D - choose molecule
- select frequency via pull-down.

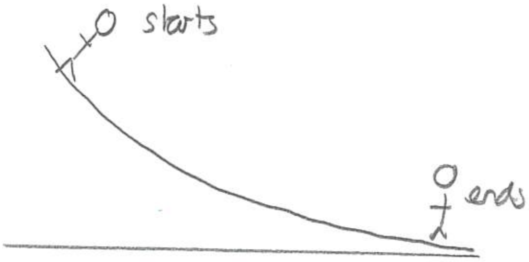
We can extend this to many other systems by including new types of energy. For example, for an electrical charge on a spring in a gravitational field

$$\text{Total } E = \underset{\text{motion}}{\underset{\downarrow}{KE}} + \underset{\text{gravity}}{\underset{\downarrow}{PE}} + \underset{\text{spring}}{\underset{\downarrow}{E_{elastic}}} + \underset{\text{charges.}}{\underset{\downarrow}{E_{electric}}}$$

When done properly the total energy will be conserved. It appears that energy conservation may always be true.

Friction and energy

Consider a realistic skater situation where the track has friction



DEMO: PHET ESP

- create gentle track.
- high friction

We can ask if

$$E = KE + PE$$

stays constant.

	KE	PE	E
start	0	positive	positive
end	0	0	0

Quiz! 70% -70%

Clearly this does not stay constant and it appears that the friction is subtracting from the energy. Observations of the effects of friction suggest how to resolve this.

DEMO: Rub hands - warming

The explanation of this comes from thermal physics.

Temperature of a system of atoms → Associated with energies (invisible) of atoms

Thermal Energy (Internal Energy)

Thus in the skater situation, some of the kinetic and potential energy must have been converted into thermal energy

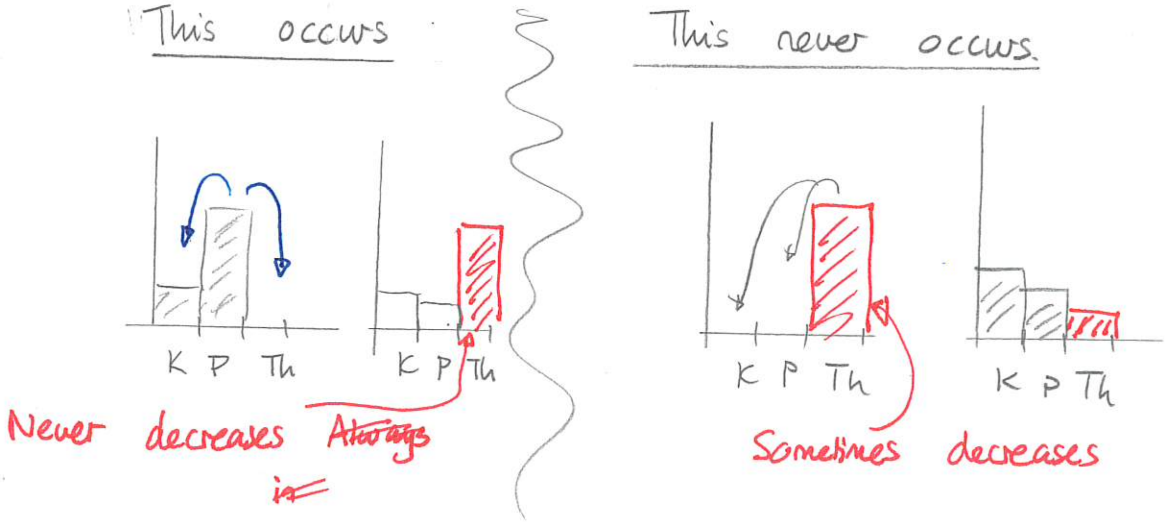
DEMO: Show ESP energy bar graph

	KE	PE	Thermal E	E
Start	0	1000J	20000J	21000J
End	0	0	21000J	21000J

Energy transformations and thermal energy

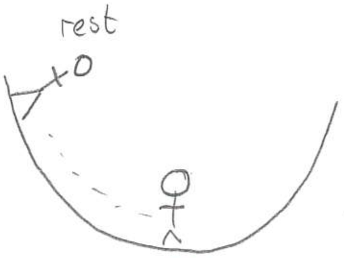
For mechanical systems energy can usually be transferred between types but it appears that the transfer of energy is a one-way process.

DEMO : ESP Basics — Friction



In this sense thermal energy is a form of waste energy which cannot be recovered by ordinary means. We would like to quantify the extent to which energy is wasted.

Energy efficiency



Therm E ≡ waste
KE = useful

For the skater we could consider the motion at the bottom of the ramp. Then, thinking that speed is useful we could describe (at lowest point)

- useful energy ≡ kinetic energy
- waste energy ≡ thermal energy.

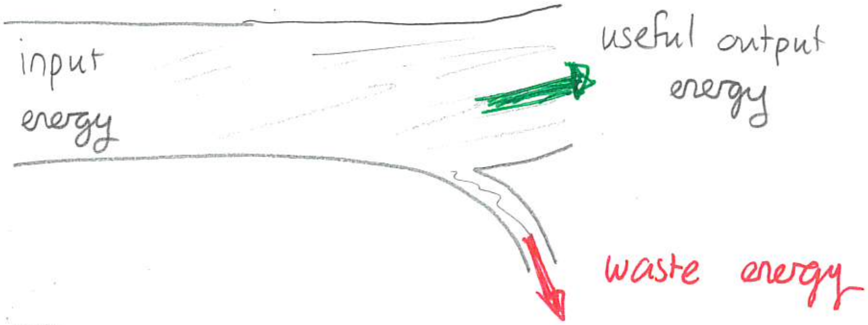
How much of each we have depends on the total energy. We can get the total energy from the initial energy. We then say

- input energy ≡ initial (potential) energy

We have

$$\boxed{\text{useful (output) energy} + \text{waste energy} = \text{input energy}}$$

We can view this as a flow (read left to right)



Efficiency.

We aim to quantify how efficient energy transfer is.

Quiz2 90%

Quiz3 30%

What matters is the fraction of energy converted into useful energy.
We define.

The energy efficiency of a process is

$$\text{energy efficiency} = \frac{\text{useful output energy}}{\text{input energy}}$$

1 Energy efficiency and skaters

A skater is at rest at the top of a ramp and skates down reaching a low point at the ground level. In all cases the initial potential energy of the skater is 4000J.

a) The skater uses a more efficient skateboard and reaches the low point with a kinetic energy of 3000 J. Determine the thermal energy at the bottom of the ramp. Determine the efficiency of the process.

b) The skater uses a more efficient skateboard and reaches the low point with a kinetic energy of 1000 J. Determine the thermal energy at the bottom of the ramp. Determine the efficiency of the process.

Answer: a) Total energy = 4000J

	KE	PE	Therm E	Total E
Top	0J	4000J	0J	4000J
Bottom	3000J	0J	1000J	4000J

height = 0

$$\text{efficiency} = \frac{3000J}{4000J} = 0.75 \qquad \sim 75\%$$

b) Reconstruct table

	KE	PE	Therm E	Total E
Top	0J	4000J	0J	4000J
Bottom	1000J	0J	3000J	4000J

$$\text{efficiency} = \frac{1000J}{4000J} = 0.25 \qquad \sim 25\%$$