Physics 4A
Chapter 10: Interactions and Potential Energy

“People of mediocre ability sometimes achieve outstanding success because they don't know when to quit. Most people succeed because they are determined to.” – George Allen

“*You're on the road to success when you realize that failure is only a detour.****”*** – unknown

"One important key to success is self-confidence. An important key to self-confidence is preparation." – Arthur Ashe

Reading: pages 231 – 254

Outline:

⇒ the energy principle
⇒ conservative and non-conservative forces
    potential energy
⇒ gravitational potential energy
⇒ elastic potential energy
⇒ energy bar charts (*if time – if not read on your own*)
⇒ conservation of energy
⇒ energy diagrams (*if time – if not read on your own*)
⇒ force and potential energy (*if time – if not read on your own*)

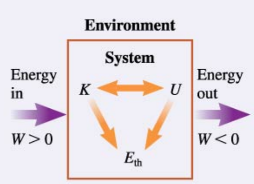
GENERAL PRINCIPLES

The Energy Principle Revisited

- Energy is *transformed* within the system.
- Energy is *transferred* to and from the system by work W.

Two variations of the energy principle are

$$\Delta E_{sys} = \Delta K + \Delta U + \Delta E_{th} = W_{ext}$$
$$K_i + U_i + W_{ext} = K_f + U_f + \Delta E_{th}$$



Basic energy model

Solving Energy Problems

MODEL Define the system.

VISUALIZE Draw a before-and-after pictorial representation and an energy bar chart.

SOLVE Use the energy principle:

$$K_i + U_i + W_{ext} = K_f + U_f + \Delta E_{th}$$

ASSESS Is the result reasonable?

Law of Conservation of Energy

- **Isolated system:** $W_{ext} = 0$. The total system energy $E_{sys} = K + U + E_{th}$ is conserved. $\Delta E_{sys} = 0$.
- **Isolated, nondissipative system:** $W_{ext} = 0$ and $W_{diss} = 0$. The **mechanical energy** $E_{mech} = K + U$ is conserved: $K_i + U_i = K_f + U_f$.

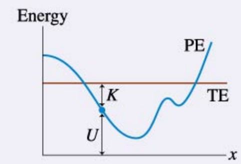
IMPORTANT CONCEPTS

Potential energy, or *interaction energy,* is energy stored inside a system via interaction forces. The energy is stored in *fields.*

- Potential energy is associated only with **conservative forces** for which the work done is independent of the path.
- Work W_{int} by the interaction forces causes $\Delta U = -W_{int}$.
- Force $F_s = -dU/ds = -$(slope of the potential energy curve).
- Potential energy is an energy of the system, not an energy of a specific object.

Energy diagrams show the potential-energy curve PE and the total mechanical energy line TE.

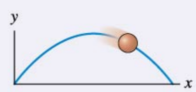
- From the axis to the curve is U. From the curve to the TE line is K.
- **Turning points** occur where the TE line crosses the PE curve.
- Minima and maxima in the PE curve are, respectively, positions of **stable** and **unstable equilibrium.**



APPLICATIONS

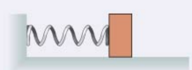
Gravitational potential energy is an energy of the earth + object system:

$$U_G = mgy$$

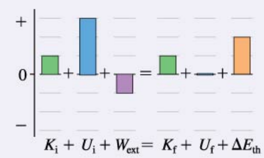


Elastic potential energy is an energy of the spring + attached objects system:

$$U_{Sp} = \frac{1}{2}k(\Delta s)^2$$



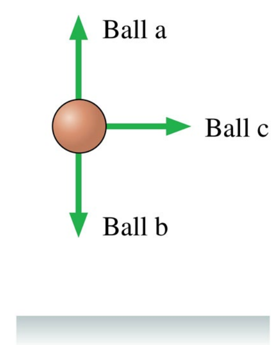
Energy bar charts show the energy principle in graphical form.



Questions and Example Problems from Chapter 10

Conceptual Question 10.2
Can kinetic energy ever be negative? Can gravitational potential energy ever be negative? For each, give a plausible reason for your answer without making use of any equations.

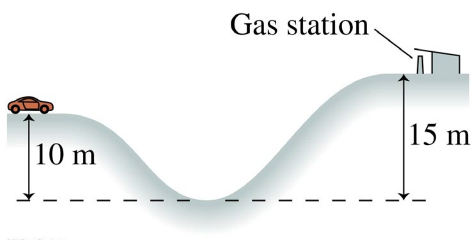
Conceptual Question 10.4
The three balls in the figure, which have equal masses, are fired with equal speeds from the same height above the ground. Rank in order, from largest to smallest, their speed v_a, v_b, and v_c as they hit the ground. Explain.



Problem 10.8
What minimum speed does a 100 g puck need to make it to the top of a 3.0-m-long, 20° frictionless ramp?

Problem 10.10
A 20 kg child is on a swing that hangs from 3.0-m-long chains. What is her maximum speed if she swings out to a 45° angle?

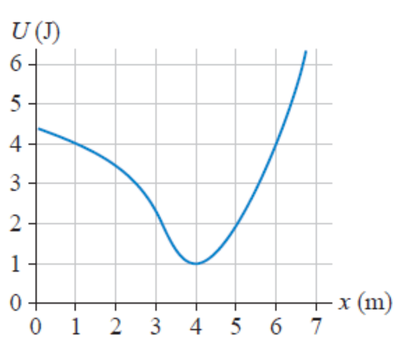
Problem 10.11
A 1500 kg car traveling at 10 m/s suddenly runs out of gas while approaching the valley shown in the figure. The alert driver puts the car in neutral so that it will roll. What will be the car's speed as it coasts into the gas station on the other side of the valley?



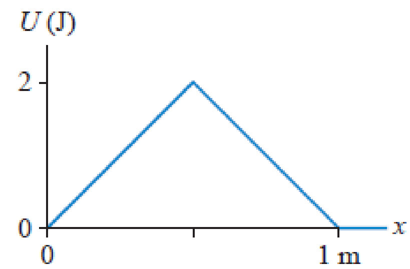
Problem 10.13
A cannon tilted up at a 30° angle fires a cannon ball at 80 m/s from atop a 10-m-high fortress wall. What is the ball's impact speed on the ground below?

Problem 10.20
As a 15,000 kg jet plane lands on an aircraft carrier, its tail hook snags a cable to slow it down. The cable is attached to a spring with spring constant 60,000 N/m. If the spring stretches 30 m to stop the plane, what was the plane's landing speed?

Problem 10.24
The figure below is the potential-energy diagram for a 20-g particle that is released from rest at x = 1.0 m. **(a)** Will the particle move to the right or to the left? How can you tell? **(b)** What is the particle's maximum speed? At what position does it have this speed? **(c)** Where are the turning points of the motion?



Problem 10.34
The figure shows the potential energy U of a particle that moves along the x-axis. Draw a graph of the force F_x as a function of position x.



Problem 10.45
A block of mass *m* slides down a frictionless track, then around the inside of a circular loop-the-loop of radius R. From what minimum height *h* must the block start to make it around without falling off? Give your answer as a multiple of R.

Problem 10.48
Sam, whose mass is 75 kg, straps on his skis and starts down a 50-m-high, 20° frictionless slope. A strong headwind exerts a *horizontal* force of 200 N on him as he skies. Use work and energy to find Sam's speed at the bottom.

Problem 10.49
A horizontal spring with a spring constant 100 N/m is compressed 20 cm and used to launch a 2.5 kg box across a frictionless, horizontal surface. After the box travels some distance, the surface becomes rough. The coefficient of kinetic friction of the box on the surface is 0.15. Use work and energy to find how far the box slides along the rough surface before stopping.

Problem 10.69 (challenging)
A pendulum is formed from a small ball of mass m on a string of length L. As the figure shows, a peg is height h = L/3 above the pendulum's lowest point. From what minimum angle θ must the pendulum be released in order for the ball to go over the top of the peg without the string going slack?