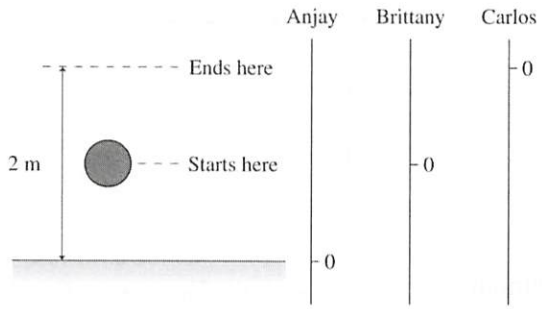
10 Interactions and Potential Energy

10.1 Potential Energy

10.2 Gravitational Potential Energy

1. Below we see a 1 kg object that is initially 1 m above the ground and rises to a height of 2 m. Anjay, Brittany, and Carlos each measure its position, but each of them uses a different coordinate system. Fill in the table to show the initial and final gravitational potential energies and ΔU as measured by our three aspiring scientists.

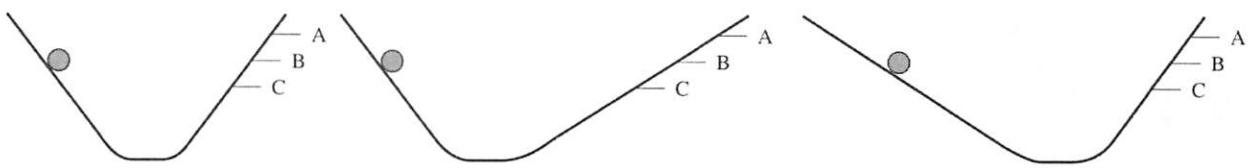


	U_i	U_f	ΔU
Anjay			
Brittany			
Carlos			

2. A roller coaster car rolls down a frictionless track, reaching speed v_f at the bottom.
   a. If you want the car to go twice as fast at the bottom, by what factor must you increase the height of the track?

   b. Does your answer to part a depend on whether the track is straight or not? Explain.

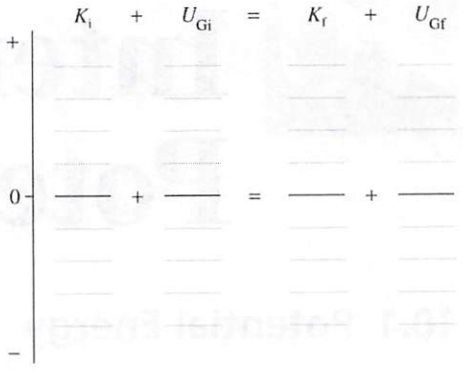
3. Below are shown three frictionless tracks. A ball is released from rest at the position shown on the left. To which point does the ball make it on the right before reversing direction and rolling back? Point B is the same height as the starting position.



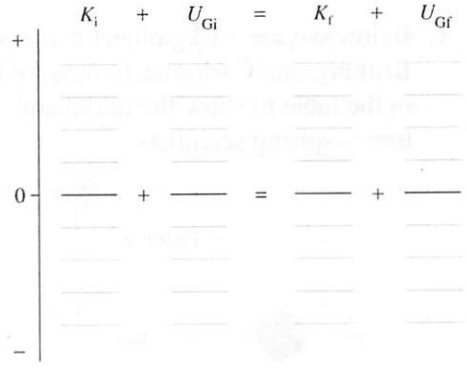
Makes it to _____ Makes it to _____ Makes it to _____

Exercises 4–6: Draw an energy bar chart to show the energy transformations for the situation described.

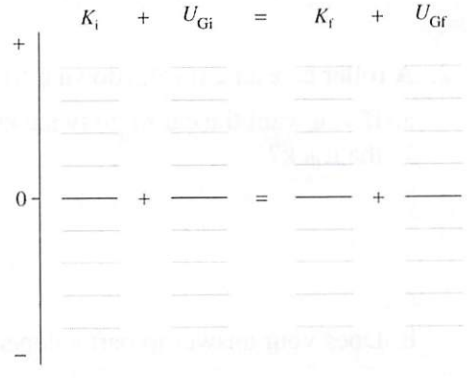
4. A car runs out of gas and coasts up a hill until finally stopping.



5. A pendulum is held out at 45° and released from rest. A short time later it swings through the lowest point on its arc.



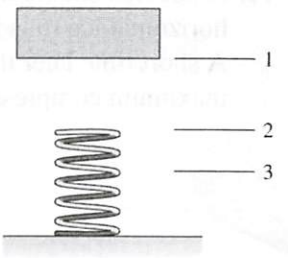
6. A ball starts from rest on the top of one hill, rolls without friction through a valley, and just barely makes it to the top of an adjacent hill.



7. What energy transformations occur as a box slides up a gentle but slightly rough incline until stopping at the top?

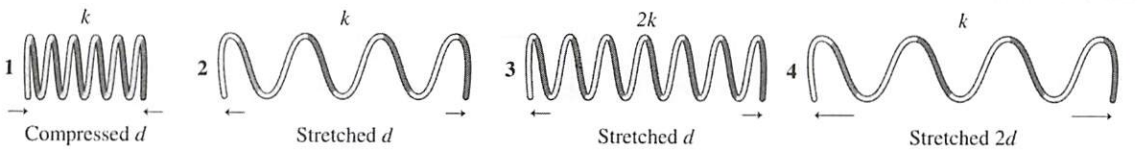
10.3 Elastic Potential Energy

8. A heavy object is released from rest at position 1 above a spring. It falls and contacts the spring at position 2. The spring achieves maximum compression at position 3. Fill in the table below to indicate whether each of the quantities are +, −, or 0 during the intervals 1 → 2, 2 → 3, and 1 → 3.



	1 → 2	2 → 3	1 → 3
ΔK			
ΔU_G			
ΔU_{Sp}			

9. Rank in order, from most to least, the amount of elastic potential energy $U_{Sp\,1}$ to $U_{Sp\,4}$ stored in each of these springs.



Order:

Explanation:

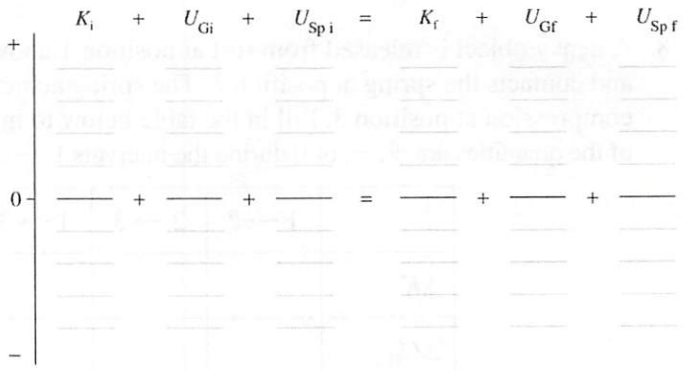
10. A spring gun shoots out a plastic ball at speed v_0 The spring is then compressed twice the distance it was on the first shot.

a. By what factor is the spring's potential energy increased?

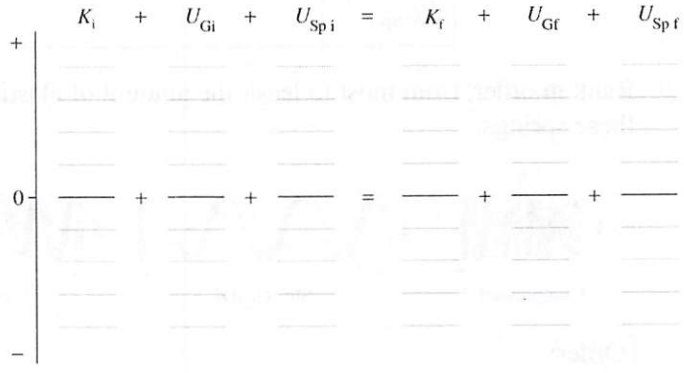
b. By what factor is the ball's launch speed increased? Explain.

Exercises 11–12: Draw an energy bar chart to show the energy transformations for the situation described.

11. A bobsled sliding across frictionless, horizontal ice runs into a giant spring. A short time later the spring reaches its maximum compression.



12. A brick is held above a spring that is standing on the ground. The brick is released from rest, and a short time later the spring reaches its maximum compression.



10.4 Conservation of Energy

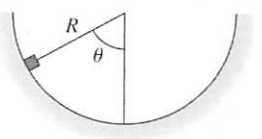
13. Give a *specific* example of a situation in which:

a. $W_{ext} \rightarrow K$ with $\Delta U = 0$ and $\Delta E_{th} = 0$.

b. $W_{ext} \rightarrow U$ with $\Delta K = 0$ and $\Delta E_{th} = 0$.

c. $W_{ext} \rightarrow E_{th}$ with $\Delta K = 0$ and $\Delta U = 0$.

14. PSS 10.1 A small cube of mass m slides back and forth in a frictionless, hemispherical bowl of radius R. Suppose the cube is released at angle θ. What is the cube's speed at the bottom of the bowl?



a. Begin by drawing a before-and-after pictorial representation. Let the cube's initial position and speed be y_i and v_i. Use a similar notation for the final position and speed.

b. At the initial position, are either K_i or U_{Gi} zero? If so, which?

c. At the final position, are either K_f or U_{Gf} zero? If so, which?

d. Does thermal energy need to be considered in this situation? Why or why not?

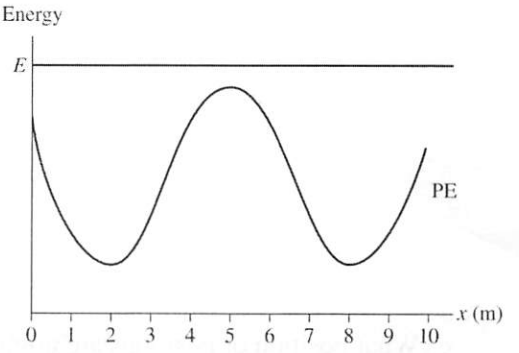
e. Write the conservation of energy equation in terms of position and speed variables, omitting any terms that are zero.

f. You're given not the initial position but the initial angle. Do the geometry and trigonometry to find y_i in terms of R and θ.

g. Use your result of part f in the energy conservation equation, and then finish solving the problem.

10.5 Energy Diagrams

15. A particle with the potential energy shown in the graph is moving to the right at $x = 0$ m with total energy E.



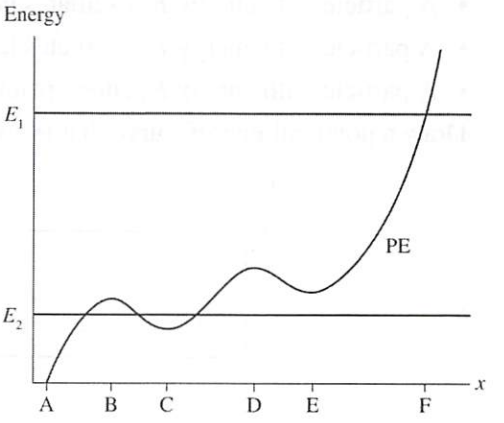
a. At what value or values of x is the particle's speed a maximum?

b. At what value or values of x is the particle's speed a minimum?

c. At what value or values of x is the potential energy a maximum?

d. Does this particle have a turning point in the range of x covered by the graph? If so, where?

16. The figure shows a potential-energy curve. Suppose a particle with total energy E_1 is at position A and moving to the right.



a. For each of the following regions of the x-axis, does the particle speed up, slow down, maintain a steady speed, or change direction?

A to B

B to C

C to D

D to E

E to F

b. Where is the particle's turning point?

c. For a particle that has total energy E_2 what are the possible motions and where do they occur along the x-axis?

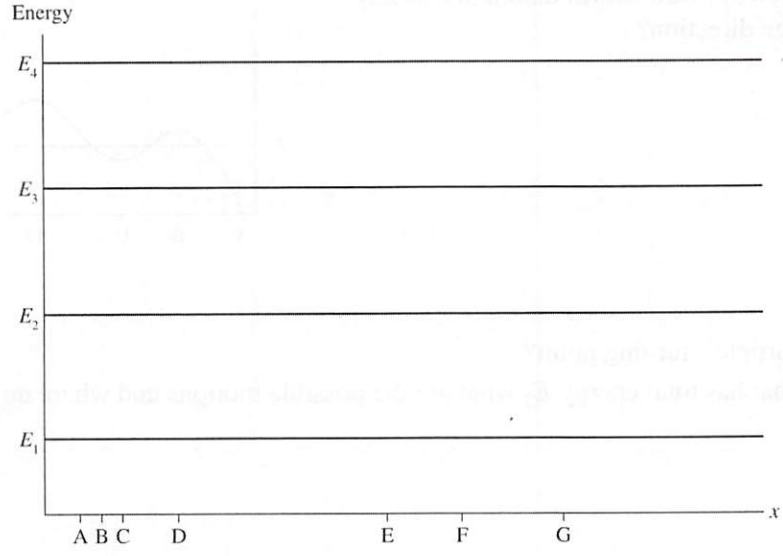
d. What position or positions are points of stable equilibrium? For each, would a particle in equilibrium at that point have total energy $\leq E_2$, between E_2 and E_1, or $\geq E_1$?

e. What position or positions are points of unstable equilibrium? For each, would a particle in equilibrium at that point have total energy $\leq E_2$, between E_2 and E_1, or $\geq E_1$?

17. Below are a set of axes on which you are going to draw a potential-energy curve. By doing experiments, you find the following information:

- A particle with energy E_1 oscillates between positions D and E.
- A particle with energy E_2 oscillates between positions C and F.
- A particle with energy E_3 oscillates between positions B and G.
- A particle with energy E_4 enters from the right, bounces at A, then never returns.

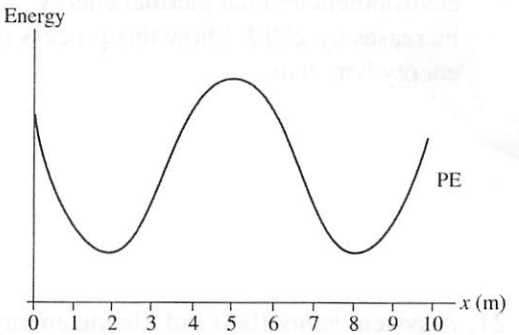
Draw a potential-energy curve that is consistent with this information.



10.6 Force and Potential Energy

10.7 Conservative and Nonconservative Forces

18. The graph shows the potential-energy curve of a particle moving along the x-axis under the influence of a conservative force.



a. In which intervals of x is the force on the particle to the right?

b. In which intervals of x is the force on the particle to the left?

c. At what value or values of x is the magnitude of the force a maximum?

d. What value or values of x are positions of stable equilibrium?

e. What value or values of x are positions of unstable equilibrium?

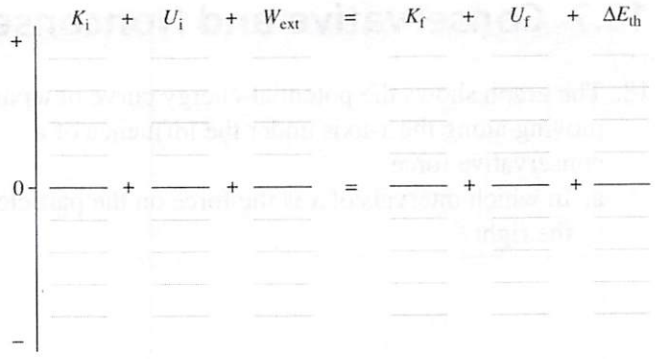
f. If the particle is released from rest at $x = 0$ m, will it reach $x = 10$ m? Explain.

19. a. If the force on a particle at some point in space is zero, must its potential energy also be zero at that point? Explain.

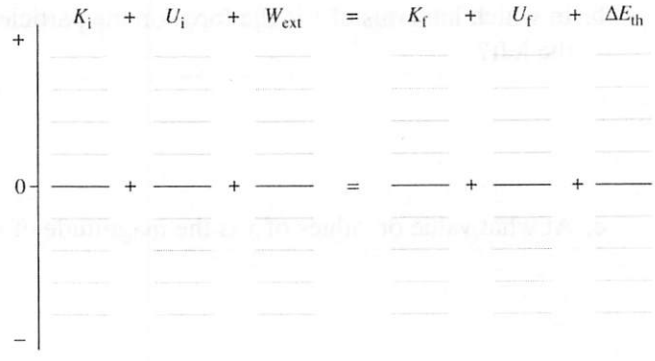
b. If the potential energy of a particle at some point in space is zero, must the force on it also be zero at that point? Explain.

10.8 The Energy Principle Revisited

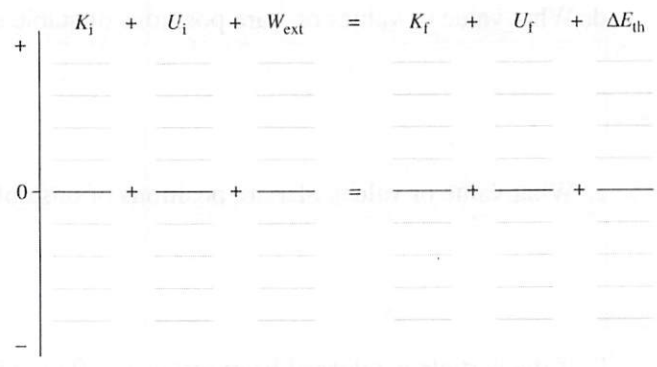
20. A system loses 1000 J of potential energy. In the process, it does 500 J of work on the environment and the thermal energy increases by 250 J. Show this process on an energy bar chart.



21. A system gains 1000 J of kinetic energy while losing 500 J of potential energy. The thermal energy increases by 250 J. Show this process on an energy bar chart.



22. A box is sitting at the top of a ramp. An external force pushes the box down the ramp, causing it to slowly accelerate. Show this process on an energy bar chart.



23. Can the following be reasonably modeled with the basic energy model? Answer Yes or No.
    a. A car skids to a halt. _____
    b. A car accelerates away from a stop sign. _____
    c. A person lifts a weight. _____
    d. A compressed spring launches a weight. _____
    e. A burner heats a gas that expands and lifts a weight. _____