10 Energy and Work

10.1 A "Natural Money" Called Energy

1. One month, John has income of \$3000, expenses of \$2500, and he sells \$300 of stocks.
   a. Can you determine John's liquid assets L at the end of the month? If so, what is L? If not, why not?

   b. Can you determine the amount by which John's liquid assets *changed* during the month? If so, what is ΔL?

2. John begins the month with \$2000 of liquid assets and \$5000 of savings. His financial activity for the month is as follows:

Day of Month	Activity
1	Receives a \$3000 paycheck; deposits it in checking
3	Spends \$500
8	Buys a \$1000 savings bond
10	Pays bills totaling \$1000
15	Receives a \$100 birthday present from Grandma
23	Sells \$1500 of stock
28	Buys a \$1200 bicycle

   a. What are John's liquid assets and saved assets at the end of the month?

   b. Show that John's monetary relationship $\Delta W = I - E$ is satisfied.

10.2 The Basic Energy Model

3. What are the two primary processes by which energy can be transferred from the environment to a system?

4. Identify the energy transformations in each of the following processes (e.g., $K \rightarrow U_g \rightarrow E_{th}$)

   a. A ball is dropped from atop a tall building.

   b. A helicopter rises from the ground at constant speed.

   c. An arrow is shot from a bow and stops in the center of its target.

   d. A pole vaulter runs, plants his pole, and vaults up over the bar.

5. The kinetic energy of a system decreases and its potential energy is unchanged. What is doing work on what? That is, does the environment do work on the system, or does the system do work on the environment? Explain.

10.3 The Law of Conservation of Energy

6. Identify an appropriate system for applying conservation of energy to each of the following:

   a. A spring is used to launch a ball into the air.

   System:

   b. A spring is used to push a car on an air track.

   System:

   c. A spring is used to slide a block across a table where it stops.

   System:

   d. A car moving on an air track collides with a spring and rebounds at essentially the same speed with which it hit the spring.

   System:

7. What is meant by an *isolated system*?

8. a. A process occurs in which a system's potential energy decreases while the environment does work on the system. Does the system's kinetic energy increase, decrease, or stay the same? Or is there not enough information to tell? Explain.

   b. A process occurs in which a system's potential energy increases while the environment does work on the system. Does the system's kinetic energy increase, decrease, or stay the same? Or is there not enough information to tell? Explain.

10.4 Work

9. For each situation described below:
   - Draw a before-and-after diagram, similar to Figures 10.8 and 10.11 in the textbook.
   - Identify *all* forces acting on the particle.
   - Determine if the work done by each of these forces is positive (+), negative (–), or zero (0). Make a little table beside the figure showing *every* force and the sign of its work.

   a. An elevator moves upward.

   b. An elevator moves downward.

   c. You push a box across a rough floor.

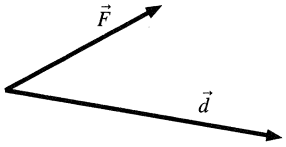
d. You slide down a steep hill.

e. A ball is thrown straight up. Consider the ball from one microsecond after it leaves your hand until the highest point of its trajectory.

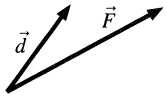
f. A car turns a corner at constant speed.

10. A 0.2 kg plastic cart and a 20 kg lead cart both roll without friction on a horizontal surface. Equal forces are used to push both carts forward a distance of 1 m, starting from rest. After traveling 1 m, is the kinetic energy of the plastic cart greater than, less than, or equal to the kinetic energy of the lead cart? Explain.

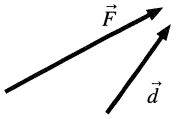
11. An object experiences a force while undergoing the displacement shown. Is the work done positive (+), negative (−), or zero (0)?

a. 

Sign = _____

b. 

Sign = _____

c. 

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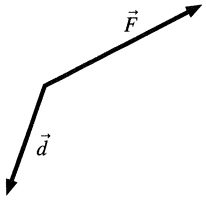
d. 

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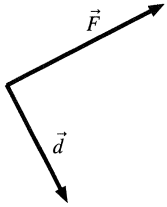
e. 

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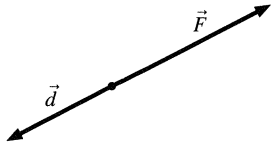
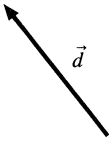
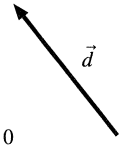
f. 

Sign = _____

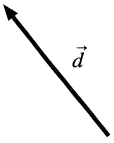
12. Each of the diagrams below shows a displacement vector for an object. Draw and label a force vector that will do work on the object with the sign indicated.

a. 

$W > 0$

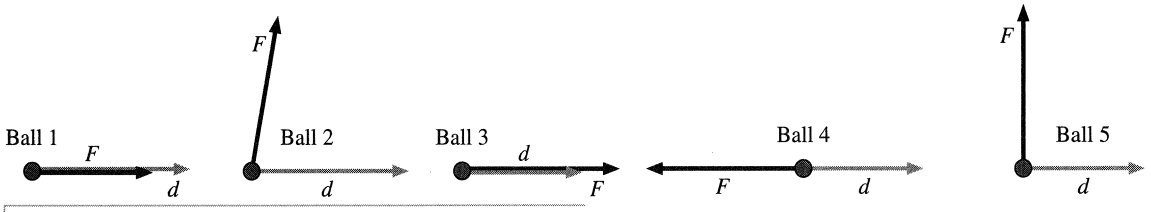
b. 

$W < 0$

c. 

$W = 0$

13. Five balls with equal initial kinetic energies experience different forces acting over different displacements, as shown by the arrows. Rank in order, from largest to smallest, the kinetic energies of the balls after being acted on by these forces.



Order:

Explanation:

10.5 Kinetic Energy

14. Can kinetic energy ever be negative?

Give a plausible *reason* for your answer without making use of any formulas.

15. a. If a particle's speed increases by a factor of three, by what factor does its kinetic energy change?

b. Particle A has half the mass and eight times the kinetic energy of particle B. What is the speed ratio v_A/v_B?

c. If a rotating skater triples her rate of rotation by decreasing her moment of inertia by 1/3, by what factor does her rotational kinetic energy change?

16. On the axes below, draw graphs of the kinetic energy of

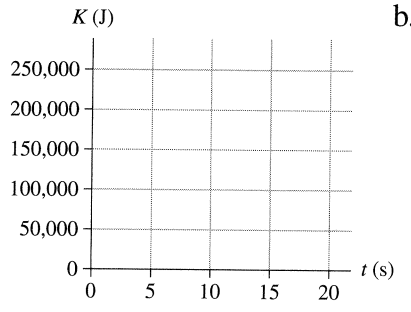
a. A 1000 kg car that uniformly accelerates from 0 to 20 m/s in 20 s.

b. A 1000 kg car moving at 20 m/s that brakes to a halt with uniform deceleration in 4 s.

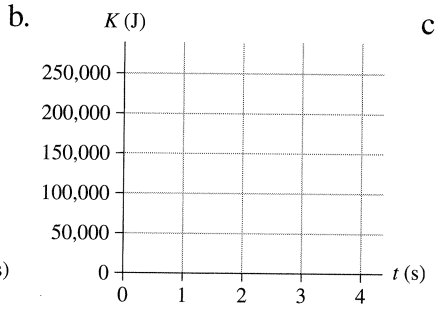
c. A 1000 kg car that drives once around a 40-m-diameter circle at a speed of 20 m/s.

Calculate K at several times, plot the points, and draw a smooth curve between them.

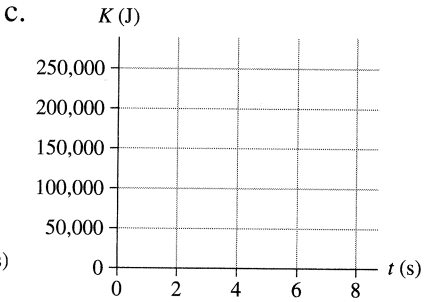
a.



b.

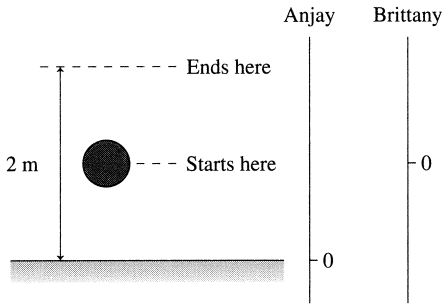


c.



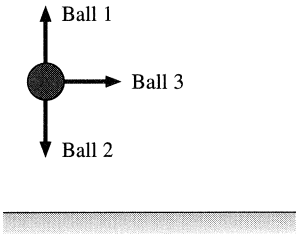
10.6 Potential Energy

17. Below we see a 1 kg object that is initially 1 m above the ground and rises to a height of 2 m. Anjay and Brittany each measure its position but use a different coordinate system to do so. Fill in the table to show the initial and final gravitational potential energies and ΔU as measured by Anjay and Brittany.



	U_i	U_f	ΔU
Anjay			
Brittany			

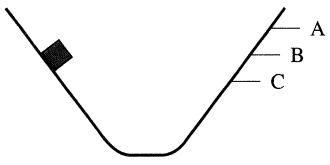
18. Three balls of equal mass are fired simultaneously with *equal* speeds from the same height above the ground. Ball 1 is fired straight up, ball 2 is fired straight down, and ball 3 is fired horizontally. Rank in order, from largest to smallest, their speeds v_1, v_2, and v_3 as they hit the ground.



Order:

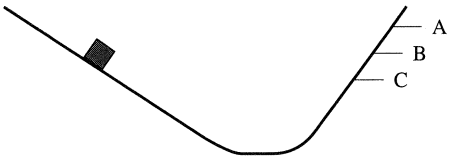
Explanation:

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



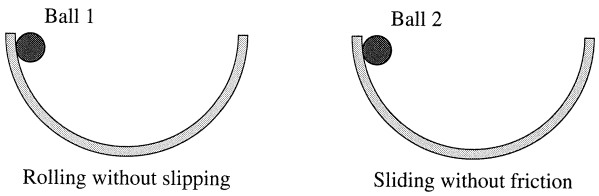
Makes it to _____

Makes it to _____

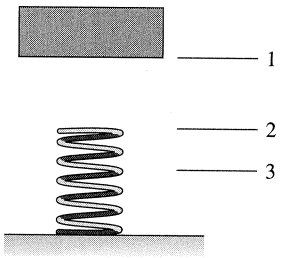


Makes it to _____

20. Two balls are released from just below the rim of two identical bowls. Ball 1 rolls down without slipping while ball 2 slides down without friction. Which ball will reach the higher point on the other side before reversing direction? Explain.

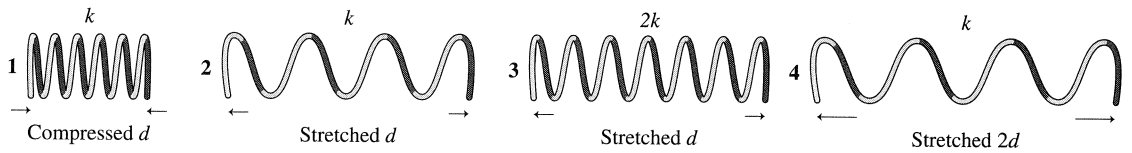


21. A heavy object is released from rest at position 1 above a spring. It falls and contacts the spring at position 2. The spring achieves maxiumum compression at position 3. Fill in the table below to indicate whether each of the quantities are +, −, or 0 during the intervals 1→2, 2→3, and 1→3.



	1→2	2→3	1→3
ΔK			
ΔU_g			
ΔU_s			

22. Rank in order, from most to least, the amount of elastic potential energy $(U_s)_1$ to $(U_s)_4$ stored in each of these springs.



Order:

Explanation:

10.7 Thermal Energy

23. A car traveling at 60 mph slams on its brakes and skids to a halt. What happened to the kinetic energy the car had just before stopping?

24. What energy transformations occur as a skier glides down a gentle slope at constant speed?

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

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

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

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

d. $W \rightarrow E_{th}$ with $\Delta K = 0$ and $\Delta U = 0$.

e. $U \rightarrow E_{th}$ with $\Delta K = 0$ and $W = 0$.

10.8 Further Examples of Conservation of Energy

26. If a solid disk and a circular hoop of the same mass and radius are released from rest at the top of a ramp and allowed to roll to the bottom, the disk will get to the bottom first. *Without referring to equations*, explain why this is so.

10.9 Energy in Collisions

27. Ball 1 with an initial speed of 14 m/s has a perfectly elastic collision with ball 2 that is initially at rest. Afterward, the speed of ball 2 is 21 m/s.

    a. What will be the speed of ball 2 if the initial speed of ball 1 is doubled?

    b. What will be the speed of ball 2 if the mass of ball 1 is doubled?

28. You can dive into a swimming pool of water from a high diving board without being hurt, but to dive into an empty pool from a much lower distance might be fatal? Why the difference?

29. Consider a perfectly elastic collision in which a moving ball 1 strikes an initially stationary ball 2. Is ball 1 more likely to recoil backwards if it is moving very fast (large forward momentum) or moving slowly (small forward momentum) assuming that ball 2 is identical in each case? Or does the speed of ball 1 matter? Explain.

30. Consider a perfectly elastic collision in which a moving ball 1 strikes a initially stationary ball 2.
    a. Under what circumstances, if any, will ball 1 come to a stop?

    b. Under what circumstances, if any, will ball 1 recoil backwards?

    c. Under what circumstances, if any, will ball 1 continue moving forward?

    d. Is it possible for ball 1 to move forward or backwards at a greater speed than its speed just before the collision?

10.10 Power

31. a. If you push an object 10 m with a 10 N force in the direction of motion, how much work do you do on it?

    b. How much power must you provide to push the object in 1 s? In 10 s? In 0.1 s?