Kinetic and Potential Energy Worksheet

24 problems + 3 challenge
Answer key at the back

Name _____ Class _____ Date _____

Directions. Use g = 9.8 m/s², neglect air resistance, and treat surfaces as frictionless unless a friction coefficient is given. Before you write an equation, name the system and say where the zero level for U_g is. Keep unrounded values between steps and round final answers to three significant figures.

Part A: kinetic energy. Part B: gravitational potential energy. Part C: spring potential energy. Part D: kinetic and potential energy together. Problems 25 to 27 are a challenge set.

$K = \frac{1}{2}mv^2$	$\Delta U_g = mg\Delta y$	$U_s = \frac{1}{2}k(\Delta x)^2$	$U_G = -Gm_1m_2/r$

Part A: Kinetic energy

K = ½mv², ratios, direction, and reference frames.

1 A 1,200 kg car travels at 15.0 m/s. Find its kinetic energy.

Answer: _____

2 A 0.145 kg baseball has 120 J of kinetic energy. How fast is it moving?

Answer: _____

3 A cyclist and her bike have a combined mass of 75.0 kg. Find their kinetic energy at 4.00 m/s and at 8.00 m/s. By what factor did the kinetic energy increase?

Answer: _____

4 A truck has three times the mass of a car, and the car moves twice as fast as the truck. Which has more kinetic energy, and by what factor?

Answer: _____

5 A 0.500 kg ball moving east at 6.00 m/s bounces off a wall and moves west at 6.00 m/s. Find (a) the change in its kinetic energy and (b) the change in its velocity.

Answer: _____

6 A 60.0 kg passenger walks toward the front of a train at 1.50 m/s relative to the train. The train moves forward at 20.0 m/s relative to the ground. Find the passenger's kinetic energy measured by (a) a seated passenger on the train and (b) a person standing on the platform.

Answer: _____

Part B: Gravitational potential energy

$\Delta U_g = mg\Delta y$, the zero level, and path independence.

7 A 2.50 kg book is lifted from the floor to a shelf 1.80 m above it. Find the change in gravitational potential energy of the book-Earth system.

Answer: _____

8 A 1.20 kg flowerpot sits on a balcony railing 6.00 m above the sidewalk. A window ledge is 2.50 m above the sidewalk. Find U_g of the pot-Earth system with the zero level at (a) the sidewalk, (b) the window ledge, and (c) the railing. (d) The pot falls to the sidewalk. Find ΔU_g for each choice of zero level.

Answer: _____

9 A 65.0 kg hiker climbs from a trailhead at an elevation of 1,240 m to a summit at 2,010 m. (a) Find the change in gravitational potential energy of the hiker-Earth system. (b) She returns to the trailhead by a longer trail. What is ΔU_g for the whole round trip?

Answer: _____

10 A pumped storage hydropower plant moves water from a lower reservoir to an upper reservoir 250 m higher. (a) By how much does the gravitational potential energy of the water-Earth system increase for each cubic meter of water lifted? A cubic meter of water has a mass of 1,000 kg. (b) Ignoring losses, how many cubic meters must be lifted to store 1.00 MWh, which is 3.60×10^9 J?

Answer: _____

11 Two students move identical 12.0 kg boxes from the ground floor to a landing 7.20 m higher. One carries her box up a staircase. The other carries his up a ramp 30.0 m long. Compare the changes in gravitational potential energy of the two box-Earth systems.

Answer: _____

12 A 0.250 kg stone falls from a bridge deck to a river 15.0 m below. Take the zero level at the deck. (a) Find U_g of the stone-Earth system when the stone reaches the water surface. (b) Explain why the negative sign is not an error.

Answer: _____

Part C: Spring potential energy

$U_s = \frac{1}{2}k(\Delta x)^2$, stretch from the natural length, and force graphs.

13 A spring with k = 300 N/m is stretched 0.120 m from its natural length. Find the elastic potential energy stored in the spring.

Answer: _____

14 A spring stores 5.00 J when it is compressed 4.00 cm. How much energy does it store when compressed (a) 8.00 cm and (b) 2.00 cm?

Answer: _____

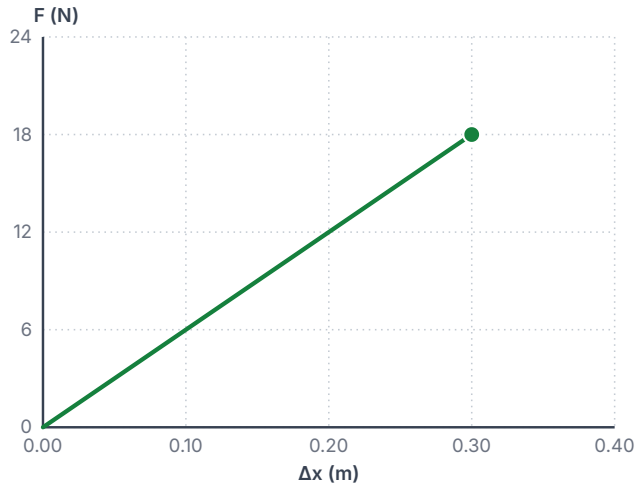
15 A spring stores 0.900 J when it is stretched 0.150 m. Find (a) its spring constant and (b) the force needed to hold it at that stretch.

Answer: _____

16 A spring has a natural length of 25.0 cm and k = 120 N/m. It is stretched to a total length of 36.0 cm. (a) Find the energy stored. (b) A student uses Δx = 0.360 m. What energy does the student get, and what is the mistake?

Answer: _____

17 The graph shows the force needed to hold a spring stretched by Δx. Find (a) the spring constant and (b) the energy stored at Δx = 0.300 m, using the area under the graph.



KEY

———	Force needed to hold the spring at stretch Δx
●	Δx = 0.300 m, F = 18.0 N

Answer: _____

18 A spring with k = 500 N/m is stretched from 0.100 m to 0.200 m. (a) Find the increase in the energy stored. (b) Is the increase equal to the energy stored at 0.100 m? Explain.

Answer: _____

Part D: Kinetic and potential energy together

No friction and no outside work, so K + U stays constant for the system named.

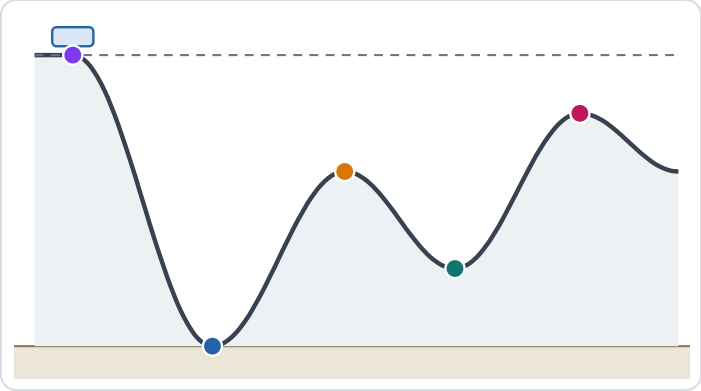
19 A 0.200 kg ball is dropped from rest 5.00 m above the ground. Use energy to find its speed just before it lands.

Answer: _____

20 A ball is thrown straight up at 12.0 m/s. Use energy to find (a) its maximum height above the launch point and (b) its speed when it is 5.00 m above the launch point.

Answer: _____

21 A cart starts from rest at point A on the frictionless track shown. (a) Rank its speeds at points A to E from greatest to least. (b) Find its speed at C. (c) Could the track include a hill 31.0 m high after E? Explain.



KEY

●	Point A: 30.0 m above the ground (start, at rest)
●	Point B: 0.0 m above the ground
●	Point C: 18.0 m above the ground
●	Point D: 8.0 m above the ground
●	Point E: 24.0 m above the ground
– – –	Starting height, 30.0 m

Answer: _____

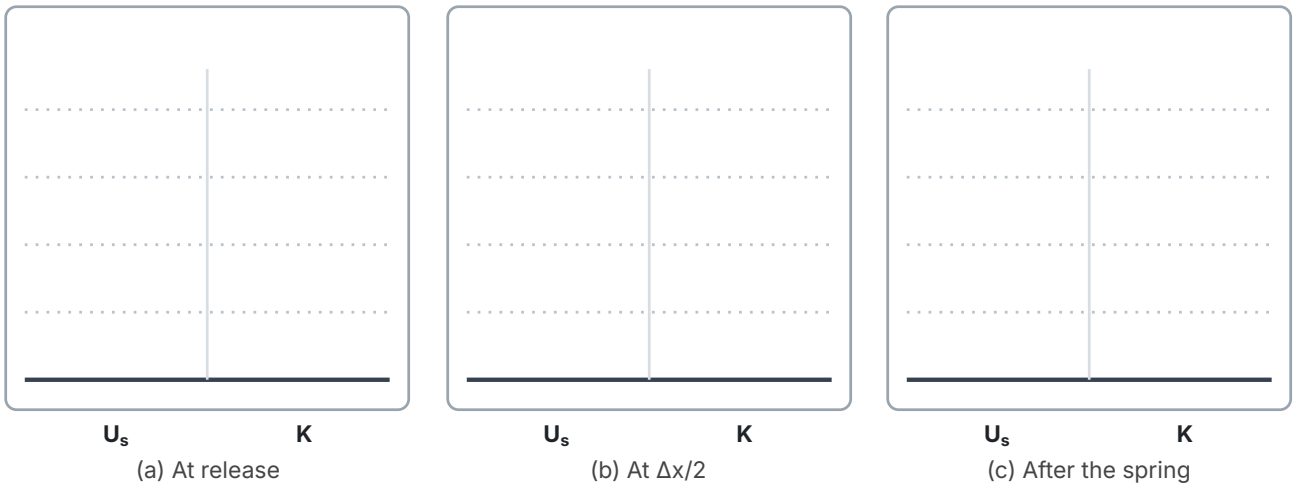
22 A toy launcher holds a spring with k = 450 N/m. The spring is compressed 0.0400 m and launches a 0.0200 kg ball straight up. How high does the ball rise above the point where it was released? Treat the spring as massless.

Answer: _____

23 A 0.800 kg pendulum bob on a 2.00 m string is pulled aside until it is 0.300 m above its lowest point and released from rest. Find (a) its speed at the lowest point and (b) its height above the lowest point when its speed is half that value.

Answer: _____

24 A block is pushed against a horizontal spring, compressing it by Δx, and released on a frictionless floor. For the block-spring system, draw energy bar charts (a) at release, (b) when the compression has fallen to Δx/2, and (c) after the block has left the spring. Use 4 units of energy at release.



(a) At release (b) At Δx/2 (c) After the spring

Answer: _____

Challenge set: problems 25 to 27

Friction on a ramp, energy far from Earth, and a spring that stops a block.

25 A 3.00 kg box is released from rest at the top of a ramp 4.00 m long, tilted at 25.0° above the horizontal, and slides down. The coefficient of kinetic friction is 0.150. Find (a) the thermal energy produced by friction during the slide and (b) the speed of the box at the bottom.

Answer:

26 A 500 kg satellite is moved from a circular orbit of radius 7.00×10^6 m to one of radius 8.00×10^6 m around Earth, which has a mass of 5.97×10^{24} kg. (a) Find the change in gravitational potential energy of the satellite-Earth system. Use $G = 6.67 \times 10^{-11}$ N·m²/kg². (b) A student uses $mg\Delta y$ with $g = 9.8$ m/s². Find that value and explain why it is too large.

Answer:

27 A 2.00 kg block slides at 4.00 m/s across a frictionless floor into a horizontal spring with k = 800 N/m. Find (a) the maximum compression of the spring and (b) the speed of the block when the compression is half the maximum.

Answer:

Answer key

g = 9.8 m/s². Final answers are rounded to three significant figures, with unrounded values carried between steps. Guide, animations, and worked examples: burketutoringinfremont.com/ap-physics-1-kinetic-and-potential-energy-problems/

Part A: Kinetic energy

1. $K = \frac{1}{2}mv^2 = \frac{1}{2}(1{,}200)(15.0)^2 =$ **1.35×10^5 J**.

2. $v = \sqrt{(2K/m)} = \sqrt{(2(120)/0.145)} =$ **40.7 m/s**.

3. At 4.00 m/s: $\frac{1}{2}(75.0)(4.00)^2 =$ **600 J**. At 8.00 m/s: $\frac{1}{2}(75.0)(8.00)^2 =$ **2,400 J**. Doubling the speed multiplied the kinetic energy by **4**.

4. Give the truck mass 3m and speed v, so the car has mass m and speed 2v. Then $K_{car} = \frac{1}{2}m(2v)^2 = 2mv^2$ and $K_{truck} = \frac{1}{2}(3m)v^2 = 1.5mv^2$. **The car** has more, by a factor of 2/1.5 = **1.33**, which is 4/3.

5. (a) $K = \frac{1}{2}(0.500)(6.00)^2 = 9.00$ J before and after, so **$\Delta K = 0$**. (b) With east as positive, $\Delta v = -6.00 - 6.00 = -12.0$ m/s, so the change is **12.0 m/s west**. Kinetic energy is a scalar, so reversing the direction does not change it.

6. (a) Relative to the train, v = 1.50 m/s: $K = \frac{1}{2}(60.0)(1.50)^2 =$ **67.5 J**. (b) Relative to the ground, v = 20.0 + 1.50 = 21.5 m/s: $K = \frac{1}{2}(60.0)(21.5)^2 = 13{,}868$ J, or **1.39×10^4 J**. Both values are correct, each in its own reference frame.

Part B: Gravitational potential energy

7. $\Delta U_g = mg\Delta y = (2.50)(9.8)(1.80) =$ **44.1 J**.

8. (a) y = 6.00 m: $U_g = (1.20)(9.8)(6.00) =$ **70.6 J**. (b) y = 6.00 − 2.50 = 3.50 m: $U_g = (1.20)(9.8)(3.50) =$ **41.2 J**. (c) **0**. (d) At the sidewalk, U_g is 0, −29.4 J, and −70.6 J for the three choices, so $\Delta U_g =$ **−70.6 J** in every case.

9. (a) $\Delta y = 2{,}010 - 1{,}240 = 770$ m: $\Delta U_g = (65.0)(9.8)(770) = 490{,}490$ J, or **4.90×10^5 J**. (b) **0**. She ends at the height where she started, and the route does not matter.

10. (a) $\Delta U_g = (1{,}000)(9.8)(250) =$ **2.45×10^6 J** per cubic meter. (b) $(3.60 \times 10^9)/(2.45 \times 10^6) = 1{,}469$, or **$1.47 \times 10^3$ m³** of water, about the volume of a cube 11.4 m on a side.

11. Both boxes rise 7.20 m, so $\Delta U_g = (12.0)(9.8)(7.20) =$ **847 J** for each. The changes are **equal**, because ΔU_g depends only on the change in height and not on the path.

12. (a) y = −15.0 m: $U_g = (0.250)(9.8)(-15.0) =$ **−36.8 J**. (b) The water is below the zero level, so y and U_g are negative there. Only changes in U_g have physical meaning, and $\Delta U_g = -36.8$ J for the fall no matter where the zero level is placed.

Part C: Spring potential energy

13. $U_s = \frac{1}{2}k(\Delta x)^2 = \frac{1}{2}(300)(0.120)^2 =$ **2.16 J**.

14. U_s depends on $(\Delta x)^2$. (a) Twice the compression stores $2^2 = 4$ times as much: **20.0 J**. (b) Half the compression stores ¼ as much: **1.25 J**.

15. (a) $k = 2U_s/(\Delta x)^2 = 2(0.900)/(0.150)^2 =$ **80.0 N/m**. (b) $F = k\Delta x = (80.0)(0.150) =$ **12.0 N**.

16. (a) $\Delta x = 36.0 - 25.0 = 11.0$ cm = 0.110 m: $U_s = \frac{1}{2}(120)(0.110)^2 =$ **0.726 J**. (b) $\frac{1}{2}(120)(0.360)^2 =$ **7.78 J**, more than ten times too large. The student used the total length of the spring. Δx is measured from the natural length.

17. (a) k is the slope: 18.0 N ÷ 0.300 m = **60.0 N/m**. (b) The area of the triangle is $\frac{1}{2}$(0.300 m)(18.0 N) = **2.70 J**, which matches $\frac{1}{2}(60.0)(0.300)^2$.

18. (a) $U_s = \frac{1}{2}(500)(0.100)^2 = 2.50$ J at 0.100 m and $\frac{1}{2}(500)(0.200)^2 = 10.0$ J at 0.200 m, so the increase is **7.50 J**. (b) **No.** The increase is three times the energy at 0.100 m, because U_s grows with $(\Delta x)^2$: $0.200^2 - 0.100^2 = 3(0.100)^2$.

Part D: Kinetic and potential energy together

19. $mgh = \frac{1}{2}mv^2$, so $v = \sqrt{(2gh)} = \sqrt{(2(9.8)(5.00))} =$ **9.90 m/s**. The mass cancels.

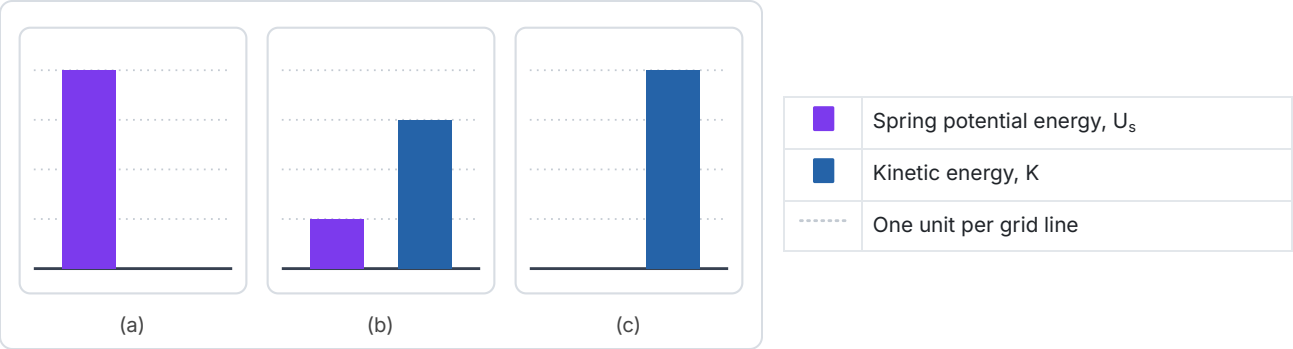
20 (a) $\frac{1}{2}mv_0^2 = mgh$, so $h = v_0^2/(2g) = 12.0^2/19.6 =$ **7.35 m**. (b) $v = \sqrt{(v_0^2 - 2gh)} = \sqrt{(144 - 98.0)} = \sqrt{46.0} =$ **6.78 m/s**, on the way up or on the way down.

21 (a) Lower points have more kinetic energy: **B, D, C, E, A**, from fastest to slowest. (b) The cart has dropped 30.0 − 18.0 = 12.0 m: $v = \sqrt{(2(9.8)(12.0))} =$ **15.3 m/s**. (c) **No.** At 31.0 m the system would need more gravitational potential energy than the total it started with, which would make K negative. A cart that starts from rest at 30.0 m on a frictionless track cannot rise above 30.0 m.

22 $U_s = \frac{1}{2}(450)(0.0400)^2 = 0.360$ J. At the highest point all of it is gravitational potential energy: $(0.0200)(9.8)h = 0.360$, so $h =$ **1.84 m** above the release point.

23 (a) $v = \sqrt{(2(9.8)(0.300))} =$ **2.42 m/s**. (b) Half the speed means ¼ of the maximum kinetic energy, so ¾ of the energy is still gravitational potential energy: $h = \frac{3}{4}(0.300) =$ **0.225 m**.

24 (a) $U_s = 4$ units and $K = 0$. (b) U_s depends on $(\Delta x)^2$, so half the compression leaves ¼ of 4 = **1 unit** of U_s and **3 units** of K. (c) $U_s = 0$ and $K =$ **4 units**. The total is 4 units in every chart, because no energy enters or leaves the block-spring system.



Challenge set: problems 25 to 27

25 $h = 4.00 \sin 25.0° = 1.69$ m, so the system starts with $U_g = (3.00)(9.8)(1.69) = 49.7$ J. (a) On the ramp $F_N = mg \cos 25.0°$, so $\Delta E_{th} = \mu_k mg \cos 25.0° \times d = (0.150)(3.00)(9.8)(0.906)(4.00) =$ **16.0 J**. (b) $K = 49.7 - 16.0 = 33.7$ J at the bottom, so $v = \sqrt{(2(33.7)/3.00)} =$ **4.74 m/s**.

26 (a) $\Delta U_G = (-GMm/r_2) - (-GMm/r_1) = GMm(1/r_1 - 1/r_2) = (6.67 \times 10^{-11})(5.97 \times 10^{24})(500)[1/(7.00 \times 10^6) - 1/(8.00 \times 10^6)] =$ **3.56×10^9 J**. (b) $mg\Delta y = (500)(9.8)(1.00 \times 10^6) =$ **4.90×10^9 J**. It is too large because g is smaller than 9.8 m/s² that far from Earth: GM/r^2 is 8.13 m/s² at 7.00×10^6 m and 6.22 m/s² at 8.00×10^6 m.

27 (a) At maximum compression the block is at rest, so $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$: $x = v\sqrt{(m/k)} = 4.00\sqrt{(2.00/800)} =$ **0.200 m**. (b) At $x = 0.100$ m, $U_s = \frac{1}{2}(800)(0.100)^2 = 4.00$ J, so $K = 16.0 - 4.00 = 12.0$ J and $v = \sqrt{(2(12.0)/2.00)} =$ **3.46 m/s**. Half the compression stores only ¼ of the energy.