AP Physics C: Mechanics
Unit 3 Practice Exercises

Directions: Show the steps required to arrive at the answer (if applicable). Use g = 9.80 m/s^2 and neglect air resistance unless otherwise stated. Work out the problems on separate page.

3.1 – Work

1. Can a normal force do work? If not, why not? If so, give an example.

2. In each case, is work done? Why or why not?
   a) A student climbs up to the 3rd floor from the 1st and then climbs back down to the starting point.
   b) A cart is pushed across the hallway at constant speed.
   c) A train accelerates on a horizontal track.
   d) A satellite does one complete orbit around Earth.

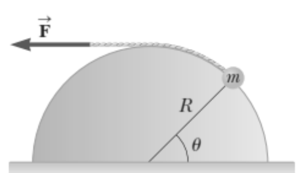
3. Link pushes a 40 kg a distance of 5 m along the level floor of a temple at constant speed with a force directed 30° below the horizontal. The coefficient between the temple floor and crate is 0.25.
   a) How much work is done by the force of the push?
   b) How much work is done by friction?
   c) How much work is done by gravity?
   d) What is the total work done?

4. A force of 100 N is observed to stretch a spring a distance of 0.4 m.
   a) What force is required to stretch the spring 0.1 m?
   b) How much work must be done to stretch the spring 0.1 beyond its unstretched length?
   c) How much work must be done to compress the spring 0.2 from its unstretched length?

5. A force $\vec{F} = (10\hat{\imath} - 3\hat{\jmath})N$ acts on a particle that goes from the origin to the position $\vec{r} = (6\hat{\imath} + 3\hat{\jmath})m$.
   a) Calculate the work done by the force on the particle.
   b) Find the angle between the force and the path of the object.

6. An object is attracted towards the origin with a force given by $F(x) = -\frac{b}{x^2}$. Calculate the work done by the force as the object moves from position x_1 to x_2 where $x_2 > x_1$.

7. *A small particle of mass *m* is pulled to the top of a frictionless half-cylinder (of radius *R*) by a light cord that passes over the top of the cylinder as shown.
   a) Assuming the particle moves at a constant speed, determine a relationship for $\vec{F}(\theta)$.
   b) Using integration, find the work done in moving the particle at constant speed from the bottom to the top of the half-cylinder.



8. When different loads hang on a spring, the spring stretches to different lengths as shown below:

F **(N)**	2.0	4.0	6.0	8.0	10	12	14	16	18	20	22
L **(mm)**	15	32	49	64	79	98	112	126	149	175	190

   a) Make a graph of the applied force versus the extension of the spring.
   b) By least-squares fitting, determine the straight line that best fits the data.
   c) Do you want to use all the data points, or should you ignore some of them?
   d) From the slope of the best-fit line, find the spring constant *k*.
   e) If the spring is extended to 105 mm, what force does it exert on the suspended object?

3.2 – Work & Kinetic Energy

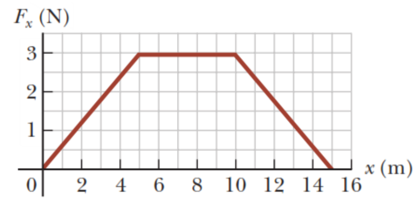
1. A student has the idea that the total work done on an object is equal to its final kinetic energy. Is this idea true always, sometimes, or never? If it is sometimes true, under what circumstances? If it is always or never true, explain why.

2. A worker pushing a 35.0-kg wooden crate at a constant speed for 12.0 m along a wood floor does 350 J of work by applying a constant horizontal force of magnitude F on the crate.

   a) Determine the value of F.
   b) If the worker now applies a force greater than F, describe the subsequent motion of the crate.
   c) Describe what would happen to the crate if the applied force is less than F.

3. A 3.00 kg particle is subject to a net force with position as shown in the figure on the right. It has an initial velocity of 2.0 m/s to the right.

   a) Find the velocity of the particle at x = 15.0 m.
   b) Find the time that has elapsed when the particle is at x = 15.0 m.



4. A car is traveling on a level road with velocity v_0 at the instant the brakes are applied. There is a coefficient of friction, μ, between the tires and road. Find the minimum stopping distance required for the car.

5. A 2.00 kg object has a velocity $(4.00\hat{\imath} - 2.00\hat{\jmath}) m/s$.

   a) What is its kinetic energy?
   b) What is the net work done on the object if its velocity changes to $(8.00\hat{\imath} + 4.00\hat{\jmath}) m/s$?

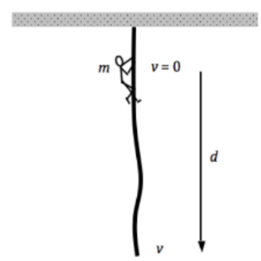
6. A car of mass M moves with an initial speed v_o on a straight horizontal road. The car is brought to rest by braking in such a way that the speed of the car is given as a function of time t by $v(t) = \sqrt{v_0^2 - \frac{Rt}{M}}$ where R is some constant. Develop an equation that expresses the time rate of change of kinetic energy.

3.3 – Work & Potential Energy

1. The equation $W = \Delta K$ states that work done on a system appears as a change in kinetic energy. It is a special-case equation, valid if there are no changes in any other type of energy such as potential or internal. Give two examples.

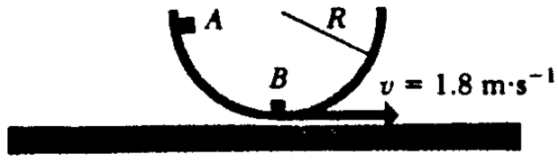
2. A ball is thrown from the roof of a 60 m tall building. The initial speed of the ball is 25 m/s. With what speed does the ball strike the ground? Use energy methods.

3. Starting from rest, a person of mass m hanging on at the top of a rope climbs down a distance d to the ground with they arrive traveling at a speed v. What is the net work done by all of the forces acting during the descent?



4. A 5.0 kg block is pushed up a frictionless plane inclined at 30° to the horizontal. It is pushed 2.0 m along the incline by a constant force of 120 N parallel to the horizontal. If the speed at the bottom is 2 m/s. What is the speed at the top? Use energy methods.

5. An object of mass 0.1 kg is released from rest at point A, which is at the top edge of a hemispherical bowl of radius R = 0.4 m. When it reaches point B at the bottom, it has a speed of 1.8 m/s. Calculate the work done by friction on the object as it moves from A to B.



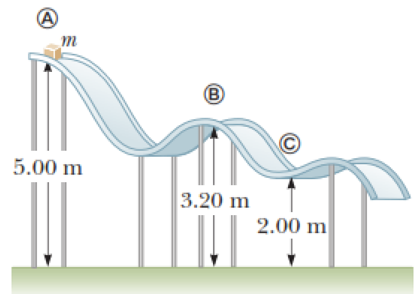
6. A skier starts at the top of a very large frictionless spherical snowball, with a very small initial velocity, and skis straight down the side. At what point does he lose contact with the snowball and flow off at a tangent. (Find the angle).

3.4 – Conservation of Energy

1. A block of mass *m* 5 5.00 kg is released from point A and slides on the frictionless track shown. Determine:

a) the block's speed at points B and C and

b) the net work done by the gravitational force on the block as it moves from point A to point C.

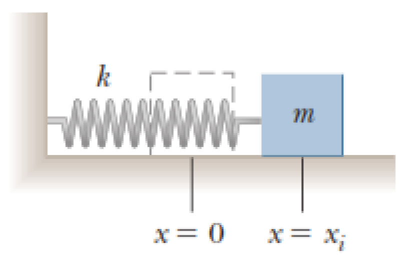


2. A sled of mass *m* is given a kick on a frozen pond. The kick imparts to the sled an initial speed of 2.00 m/s. The coefficient of kinetic friction between sled and ice is 0.100. Use energy considerations to find the distance the sled moves before it stops.

3. A block of mass $m = 2.00$ kg is attached to a spring of force constant $k = 500$ N/m as shown in. The block is pulled to a position $x = 5.00$ cm to the right of equilibrium and released from rest. Find the speed the block has as it passes through equilibrium if

a) the horizontal surface is frictionless and

b) the coefficient of friction between block and surface is 0.350.

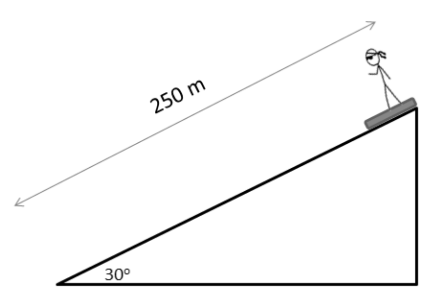


4. A 2.0 block is pushed against a spring with constant k = 400 N/m and compressed a distance of 0.3 m. The block is released from rest and moves along a frictionless horizontal surface before going up a frictionless incline that is incline 37° with the horizontal.

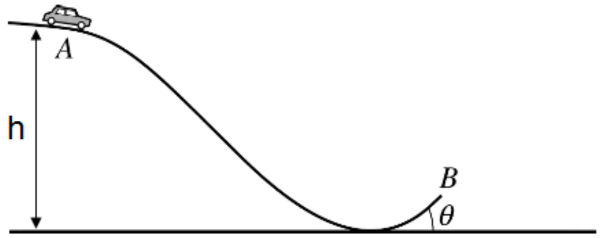
a) What is the speed of the block when it loses contact with the spring?

b) How far up the incline does the block travel before sliding back down?

5. A snowboarder slides down a snowy incline that makes a 30° incline with the horizontal as shown below. The snowboarder and board weight a combined 68.0 kg. The snowboarder slides 250 m along the incline. The coefficient of friction between the snow and the snowboard is .22. Find the velocity of the snowboarder at the bottom of the incline.



6. A car starts at point A, which a height h above the ground with zero speed. It coasts down the frictionless track shown and leaves the track at B, which makes an angle of θ with the ground and it a height of h/5 above the ground.



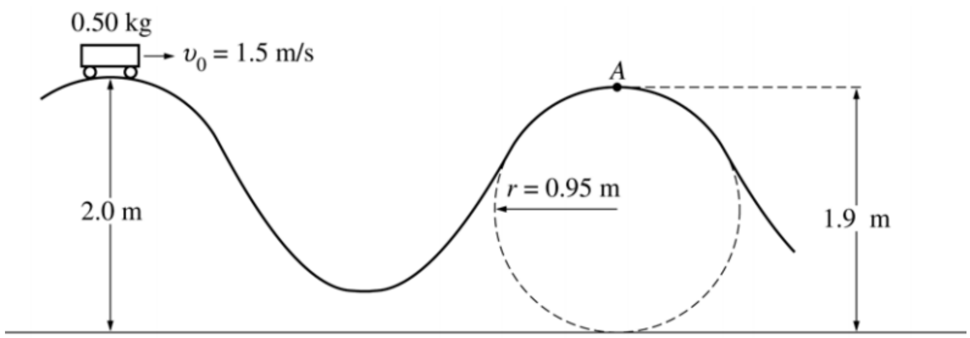
a) The highest point in car's A motion after leaving the track is not A. Briefly explain why this is so.
b) Find the speed of the car at point B.
c) Find the maximum height that car A reaches.
d) Would your answer be the same if the track were non-frictionless? Justify your answer.

7. An 80.0-kg skydiver jumps out of a balloon at an altitude of 1 000 m and opens his parachute at an altitude of 200 m.

a) Assuming the total retarding force on the skydiver is constant at 50.0 N with the parachute closed and constant at 3,600 N with the parachute open, find the speed of the skydiver when he lands on the ground.
b) Do you think the skydiver will be injured? Explain.
c) At what height should the parachute be opened so that the final speed of the skydiver when he hits the ground is 5.00 m/s?
d) How realistic is the assumption that the total retarding force is constant? Explain.

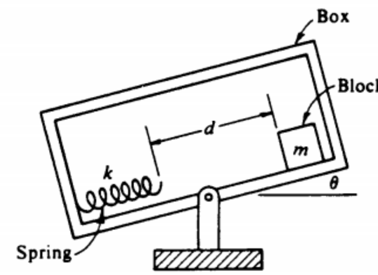
8. A belligerent spring obeys $F = -kx^2$ rather than Hooke's Law. The spring has a mass of m on its free end. The mass is pulled a distance A to the right of $x = 0$ and then released from rest. At what location will the kinetic energy of the mass equal 2.0 times the elastic potential energy stored in the spring?

9. A designer is working on a new roller coaster, and she begins by making a scale model. On the model, a car of total mass 0.50 kg moves with negligible friction along the track shown in the figure below. The car is given an initial speed $v_0 = 1.5\ m/s$ at the top of the first hill of height 2.0 m. Point A is located at height of 1.9 at the top of the second hill, the upper part of which is a circular arc of radius 0.95 m. \



a) Calculate the speed of the cart at point A.
b) Draw a free body diagram of the cart at point A.
c) Calculate the force of the track on the car at point A.
d) In order to stop the car at point A, some friction is introduced. Calculate the work that must be done by the friction force to stop the car at point A.
e) Explain how to modify the track design to cause the car to lose contact with the track at point A before descending down the track. (HINT: This occurs when there isn't sufficient force to keep the cart in a circular motion at point A).

10. An apparatus to determine coefficients of friction is shown. The box is slowly rotated counterclockwise. When the box makes an angle θ with the horizontal, the block of mass m just starts to slide, and at this instant the box is stopped from rotating. Thus at angle θ, the block slides a distance d, hits the spring of force constant k, and compresses the spring a distance x before coming to rest. Derive an expression for each of the following:

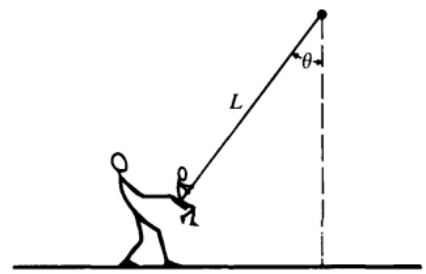


a) the coefficient of static friction

b) ΔE, the loss in total mechanical energy of the block-spring system from the start of the block down the incline to the moment at which it comes to rest on the compressed spring.

c) the coefficient of kinetic friction

11. An adult exerts a horizontal force on a swing that is suspended by a rope of length L, holding it at an angle θ with the vertical. The child in the swing has a weight W and dimensions that are negligible compared to L. The weights of the rope and of the seat are negligible. In terms of W and θ, determine:

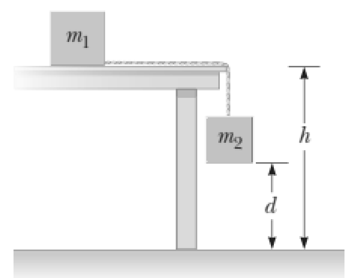


a) the tension in the rope

b) the horizontal force exerted by the adult.

c)The adult releases the swing from rest. Determine the tension in the rope as the swing passes through its lowest point.

12. As shown in Figure P8.46, a light string that does not stretch changes from horizontal to vertical as it passes over the edge of a table. The string connects m_1, a 3.50-kg block originally at rest on the horizontal table at a height h = 1.20 m above the floor, to m_2, a hanging 1.90-kg block originally a distance d = 0.900 m above the floor. Neither the surface of the table nor its edge exerts a force of kinetic friction. The blocks start to move from rest. The sliding block m_1 is projected horizontally after reaching the edge of the table. Consider the two blocks plus the Earth as the system.



a) Find the speed at which m_1 leaves the edge of the table using energy methods.

b) Find the impact speed of m_1 on the floor using energy methods.

c) What is the shortest length of the string so that it does not go taut while m is in flight?

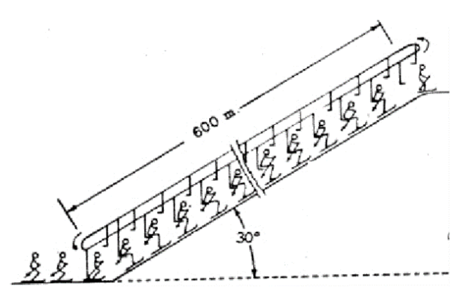
d) Is the energy of the system when it is released from rest equal to the energy of the system just before m_1 strikes the ground? Why or why not?

<u>3.5 – Power</u>

1. A 21800 kg car, initially at rest, is accelerated along a horizontal roadway at 3 m/s^2. What is the average power required to bring the car to a final speed of 24 m/s?

2. A man whose mass is 80 kg walks up to the 3rd floor. This is a vertical height of 16 m above ground level. If he climbs the stairs in 20 s, what is his rate of working, in terms of horsepower? (1 hp = 746)

3. A ski lift carries skiers along a 600 meter slope inclined at 30°. To lift a single rider, it is necessary to move 70 kg of mass to the top of the lift. Under maximum load conditions, six riders per minute arrive at the top. If 60 percent of the energy supplied by the motor goes to overcoming friction, what average power must the motor supply?



4. Mario drives a 350 kg go-cart at constant speed of 5 m/s on level ground. The coefficient of friction is .20.

a) Find the work done to move the go-kart forward for 20 s.

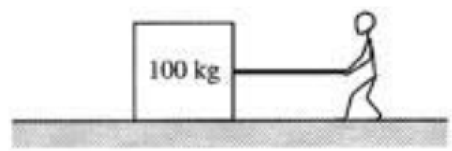
b) If the go-kart's battery supplies 14 horsepower to the motor, what is the efficiency of the motor?

5. An automobile of mass m accelerates, starting from rest, while the constant supplies a constant power P.

a) Determine an expression for the speed as a function of time.

b) Determine an expression for the displacement as a function of time.

6. The 100 kg box shown above is being pulled along the x-axis by a student. The box slides across a rough surface, and its position x varies with time t according to the equation x = $0.5t^3 + 2t$.



a) Determine the speed of the box at time t = 0.

b) Determine the following as functions of time t.

i. The kinetic energy of the box

ii. The net force acting on the box

iii. The power being delivered to the box

c) Calculate the net work done on the box in the interval t = 0 to t = 2s.

d) Indicate below whether the work done on the box by the student in the interval t = 0 to t = 2s would be greater than, less than, or equal to the answer in part c). Justify your answer