Portland State University
General Physics Workshop
Problem Set 5

Work and energy

Equations and Relations:

Newton's Laws:

- 1st: An object will stay at rest or in motion with constant velocity unless acted on by a net force.
- 2nd: $\Sigma F_x = ma_x, \quad \Sigma F_y = ma_y$
- 3rd: Forces come in pairs. If A exerts a force on B, then B exerts a force on A with the same magnitude but in the opposite direction.

Uniform Circular Motion: $a_c = v^2 / r$

Friction: $f_s \le \mu_s N, \quad f_k = \mu_k N$

Work & Energy: $W = F_{\|}d = Fd_{\|}$,

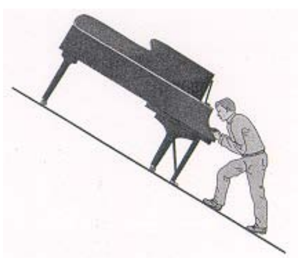
$W_{net} = \Delta KE$

$W_{nc} = \Delta KE + \Delta PE$

$KE = \frac{1}{2}mv^2$, $PE_{grav} = mgy$

Springs: $F_{sp} = kx, \quad PE_{sp} = \frac{1}{2}kx^2$

1. A 280 kg piano slides 4.3 m down a 30° incline and is kept from accelerating by a man who is pushing back on it parallel to the incline. The effective coefficient of kinetic friction is 0.40. Calculate:



   (a) the force exerted by the man,
   (b) the work done by the man on the piano, the work done by the friction force,
   (d) the work done by the force of gravity, and
   (e) the net work done on the piano.

2. You pick up a 4-kg can of paint from the ground and lift it to a height of 2 m.
   (a) How much work do you do on the can of paint?
   (b) You hold the can stationary for half a minute, waiting for a friend on a ladder to take it. How much work do you do during this time?
   (c) Your friend decides against the paint, so you lower it back to the ground. How much work do you do on the can as you lower it?

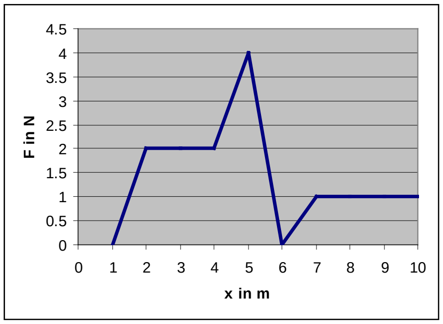
3. A spring is a device where the force it exerts is directly proportional to its displacement from its natural (unstretched) length. The constant of proportionality is called the spring constant *k*. Draw a graph of the spring force versus its displacement. What is the work done in stretching a spring from its natural length by an amount *x*?

4. It takes 130 J of work to compress a certain spring 0.10 m.
   (a) What is the force constant of this spring?
   (b) How much work does it take to compress the spring an additional 0.10 m

Check Point

➢ *Does it always take the same work to compress a spring a certain distance?*

5. The graph shows the force on an object as it moves a distance x. What is the work done by the force when the object moves from
   (a) 1 m to 2 m?
   (b) 2 m to 4 m?
   (c) 4 m to 6 m?
   (d) 6 m to 10 m?
   (e) 1 m to 10 m?



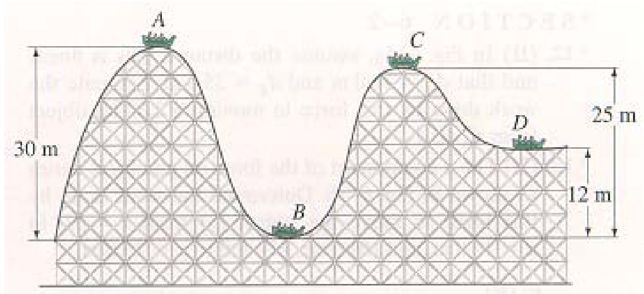
6. Please discuss the meaning of the following phrases:
   a) Kinetic energy
   b) Potential energy
   c) Conservation of mechanical energy
   d) Spring constant

Check Point

➢ *Give several examples where mechanical energy is conserved, and several where it isn't.*

7. An automobile traveling 60 km/h can brake to a stop within a distance of 20 m. If the car is going twice as fast, 120 km/h, what is its stopping distance? The maximum braking force is approximately independent of speed.

8. A roller coaster is pulled up to point A where it is released from rest. Assuming no friction, calculate the speed at points B, C and D.
   Now suppose the roller coaster passes point A with a speed of 1.70 m/s. If the average force of friction is equal to one fifth of its weight, with what speed will it reach point B? The distance traveled is 45.0 m.

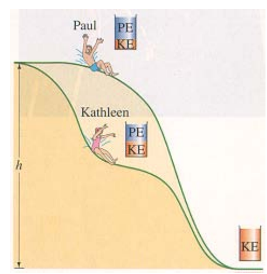


9. A 40-kg seal at an amusement park slides from rest down a ramp into the pool below. The top of the ramp is 2 m higher than the surface of the water and the ramp is inclined at an angle of 35.0° above the horizontal. If the seal reaches the water with a speed of 4.40 m/s, what is
   (a) the work done by kinetic friction and
   (b) the coefficient of kinetic friction between the seal and the ramp?

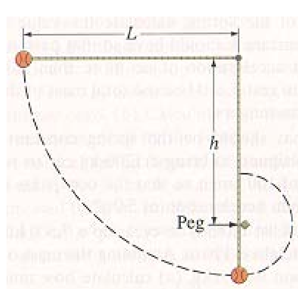
Check Point

- *Two water slides at a pool are shaped differently but start at the same height h. Two riders, Paul and Kathleen, start from rest at the same time on different slides.*

Ignoring friction which rider, Paul or Kathleen, is traveling faster at the bottom?
Who gets there first?
How would your answers change if you include friction?



10. A ball is attached to a horizontal cord of length L whose other end is fixed. (a) If the ball is released, what will be its speed at the lowest point of its path? (b) A peg is located a distance h directly below the point of attachment of the cord. If $h = 0.80L$, what will be the speed of the ball when it reaches the top of its circular path about the peg?



11. A 1.00 kg pendulum bob on a string 2 m long is released with a velocity of 4 m/s when the support string makes an angle of 30.0 degrees with the vertical.

a.) What is the angle with the vertical the bob makes at the highest point of its motion?
b.) What is the tension in the string at this point?
c.) What is the velocity of the bob at the bottom of the swing?
d.) What is the tension in the string at this point?

Additional Questions

1. Other than nuclear energy, why do we say the source of all energy comes from the sun? Specifically, what about:
   (a) wind energy
   (b) hydro-electricity
   (c) fossil fuel - coal, wood, oil, gas
   (d) food that we eat

2. You throw a ball from the ground to someone leaning out of a second story window. During the motion of the ball, does gravity do positive, negative or zero work on the ball? Explain how you arrive at your answer.

3. During this same motion of the ball (from the ground to the window above), how does the kinetic energy of the ball change (increase, decrease, or stay the same)? What is the connection between this change in KE and the work done by gravity?

4. The same ball is now dropped back to the ground. As the ball falls, does gravity do positive, negative or zero work on it? How does this affect the kinetic energy of the ball?

5. Is it possible to do work on an object that remains at rest?

6. A catcher stops a 90 mph pitch. Has the catcher done (a) positive work, (b) negative work, or (c) zero work on the ball? Explain.