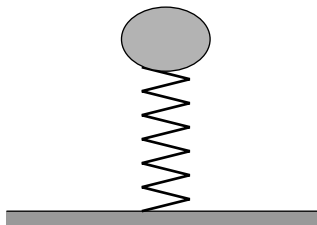


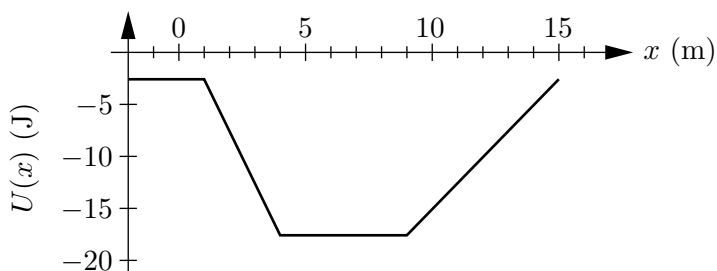
Problem Set 7
(due Thursday, February 23)

1. If the speed of an object is doubled, what happens to its kinetic energy?
2. Calculate the kinetic energies of the following objects moving at the given speeds: (a) a 110 kg football linebacker running at 8.1 m/s; (b) a 4.2 g bullet at 950 m/s; (c) the aircraft carrier *Nimitz*, 91,400 tons at 32 knots.
3. Three plums are launched from ground level, at the same initial speed. The first is launched straight upward; the second is launched at an angle, so it follows a parabolic arc; the third is launched up a frictionless incline, so it moves upward along a straight diagonal. When they reach an altitude of 5 meters above the ground, which has the greatest speed? Which has the smallest speed? What can you say about their velocities? (Please explain your reasoning.)
4. A pendulum consists of a 2.0 kg stone swinging from a 4.0 m string of negligible mass. The stone has a speed of 8.0 m/s when it passes its lowest point. (a) What is the speed when the string is at a 60° angle to the vertical? (b) What is the maximum angle of the swing of the pendulum? (c) If the system's gravitational energy is taken to be zero when the stone is at its lowest point, what is the total energy of the system? (You may wish to use the worksheet.)
5. Once again, Tarzan (mass 80 kg) plans to swing from a vine (length 10 m). This time he's initially standing on a branch, 5.0 meters above the ground, while at the lowest point of his swing his feet will be 1.0 meter above the ground. How much tension must the vine be able to withstand, in order not to break? (You may wish to use the worksheet.)
6. Consider again the original predicament of Paddy (mass 75 kg) and the barrel of bricks (mass 100 kg). Recall that both are initially at rest, then the bricks fall 25 m while Paddy rises 25 m until they collide. There is no friction in the pulley or elsewhere. Use conservation of energy to find Paddy's speed just before the collision, and comment on how this method of predicting the speed compares to the method you used earlier. (You may wish to use the worksheet.)
7. I have a rubber band that stretches 10 cm when a 500 g mass hangs from it (motionless). What is its "spring constant"? How much would it stretch if I hang an additional 500 g from it, making 1 kg total?
8. During spring semester at MIT, residents of the parallel buildings of the East Campus dorms battle one another with large catapults that are made of surgical hose mounted on a window frame. A balloon filled with dyed water is placed in a pouch attached to the hose, which is then stretched across the room and released. Assume that the catapult obeys Hooke's law ($F_x = -kx$) and has a spring constant of 100 N/m. (a) How much force is needed to stretch the catapult 5.0 m from its relaxed position? (b) How much elastic energy is stored in the catapult when it is stretched by this amount? (c) If the balloon has a mass of 1.0 kg, to what speed is it accelerated by the catapult?
9. Shown below is an 8.0 kg stone resting on a spring. The spring is compressed by 10 cm by the stone. (a) What is the spring constant? (b) Suppose that you now push the stone down an additional 30 cm. What is the elastic potential energy of the spring? (c) If you now release the stone from this position, how much gravitational potential energy does it gain as it flies

upward? (d) How high does the stone go, measured from the release point? (You may wish to use the worksheet.)



10. A 2-kg particle moving along the x axis is subject to a single force, whose corresponding potential energy graph is shown below. When the particle is at $x = 2.0$ m, its x velocity is -1.5 m/s. (a) What are the magnitude and direction of the force acting on the particle at this position? (b) Between what limits of x does the particle move? (c) What is the particle's speed when it reaches $x = 7.0$ m?



Study Guide

Kinetic energy: $K = \frac{1}{2}m|\vec{v}|^2$

Gravitational (potential) energy: $U_g = mgy$

Spring force: $|\vec{F}_s| = kx$, where x is the amount of stretch or compression. (Force and displacement are in opposite directions.)

Elastic (potential) energy: $U_s = \frac{1}{2}kx^2$

Potential energy in general: For a position-dependent force acting in the x direction, $F_x = -dU/dx$ = minus the slope of the potential energy graph.

Total mechanical energy: $E = K + U_g + U_s + \dots$ (add up all kinetic and potential energies for all particles and interactions in the system)

Total mechanical energy (kinetic plus potential) is conserved (that is, $E_{\text{final}} = E_{\text{initial}}$) provided that all forces have been taken into account as types of potential energy, although forces perpendicular to the motion can be neglected. If there are forces along or against the motion (such as most types of friction or air resistance or people pushing) that do not have associated potential energy functions, then mechanical energy is *not* conserved.