8.7 EXERCISES

Work

Ex 8.7.1. A boy pulls a 5 kg cart with a 20 N force at an angle of 30° with the horizon for some time. Over this time the cart moves a distance of 12 m on a horizontal floor. (a) Find the work done on the cart by the boy. (b) What will be the work done by the boy if he pulled with the same force horizontally instead of at an angle 30° with the horizon over the same distance?

Ans: (a) 208 N.m; (b) 240 N.m.

Ex 8.7.2. A crate of mass 200 kg is to be brought from a site on the ground floor to a third floor apartment. The workers know that they can either use the elevator first, then slide it on the third floor to the apartment or first slide the crate to another location marked C in the Fig. 8.23, and then take the elevator to the third floor and then slide it on the third floor a shorter distance.

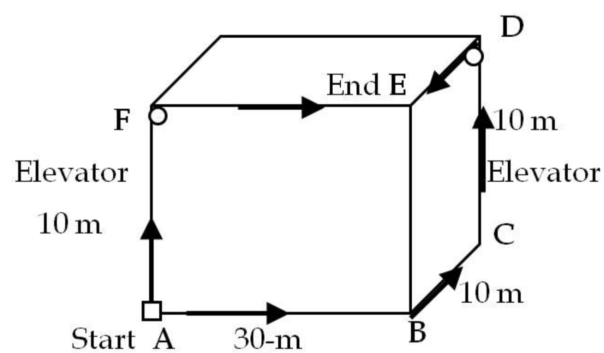

Figure 8.23: Exercise 8.7.2.

The trouble is the third floor is very rough compared to the ground floor. Given that the coefficient of kinetic friction between the crate and the ground floor is 0.1 and between the crate and the third floor surface is 0.3, find the work needed by the workers for each path. Assume that the force workers need to do is just enough to slide the crate at constant velocity at zero acceleration. Note: The work by the elevator against the force of gravity is not done by the workers.

Ans: $W_{ABCDE} = 13,720\ J$, $W_{AFE} = 17,640\ J$.

Ex 8.7.3. A hockey puck is shot across a rough floor with the roughness different at different place, which can be described by a position-dependent coefficient of kinetic friction. For a puck moving along the x-axis, the coefficient of kinetic friction is the following function of x

when x is in m, $\mu(x) = 0.1 + 0.05x$. Find work done by the kinetic frictional force on the hockey puck when it has moved (a) from $x = 0$ to $x = 2$ m, and (b) from $x = 2$ m to $x = 4$ m.

Ans: (a) -0.9 N.m; (b) -1.5 N.m.

Conservation of Energy Involving Weight

Ex 8.7.4. A mysterious constant force 10 N acts horizontally on everything. The direction of the force is found to be always pointed towards a wall in a big hall. Find the potential energy of a particle due to this force when it is at a distance x from the wall assuming the potential energy at the wall to be zero.

Ans: $10x$ with x-axis pointed away from the wall and origin at the wall.

Ex 8.7.5. In an amusement park a car rolls in a track as shown in Fig. 8.24. Find the speed of the car at A, B and C. Note that the work done by the rolling friction is zero since the displacement of the point at which the rolling friction acts on the tires is momentarily at rest and therefore has a zero displacement.

Ans: $v_A = 24\ m/s$; $v_B = 14\ m/s$; $v_C = 31\ m/s$.

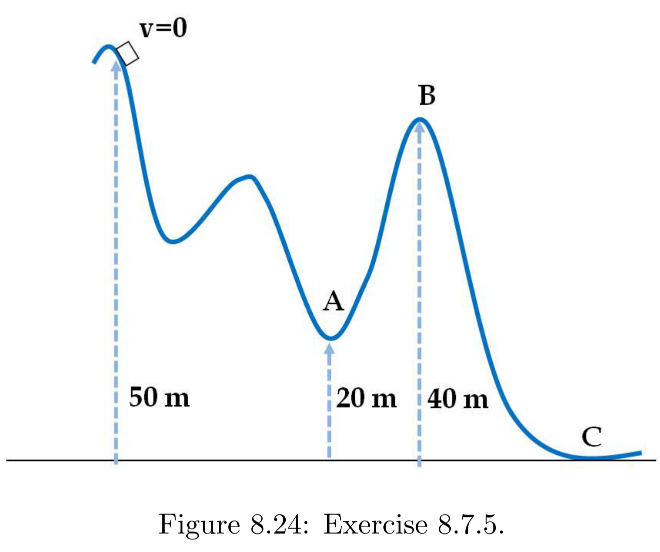

Figure 8.24: Exercise 8.7.5.

Ex 8.7.6. A 200-g steel ball is tied to a 2-m "massless" string and hung from the ceiling to make a pendulum, and then, the ball is brought to a position making a 30° angle with the vertical direction and released from rest. Ignoring the effects of the air resistance, find the speed of the ball when the string (a) is vertically down, (b) makes an angle of 20° with the vertical and (c) makes an angle of 10° with the vertical.

Ans: (a) 2.29 m/s. (b) 1.70 m/s. (c) 2.16 m/s.

Ex 8.7.7. How would your answer(s) in the Ex. 8.7.6 change if the string had a mass of 100 g distributed uniformly along the string? (Hint: No new calculations necessary.)

Conservation of Energy Involving Spring Force

Ex 8.7.8. A block of mass 300 g is attached to a spring of spring constant 100 N/m. The other end of the spring is attached to a support while the block rests on a smooth horizontal table and can slide freely without any friction. The block is pushed horizontally till the spring compresses by 12 cm, and then the block is released from rest. (a) How much potential energy was stored in the block-spring-support system when the block was just released? (b) Determine the speed of the block when it crosses the point when the spring is neither compressed nor stretched. (c) Determine the speed of the block when it has traveled a distance of 20 cm from where it was released.

Ans: (a) 0.72 J. (b) 2.2 m/s. (c) 1.6 m/s.

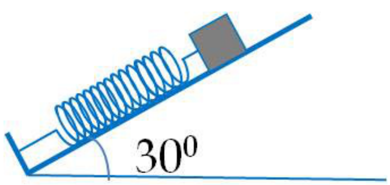

Figure 8.25: Exercise **??**.

Ex 8.7.9. A block of mass 500 g is attached to a spring of spring constant 80 N/m. The other end of the spring is attached to a support while the mass rests on a smooth surface inclined at angle of 30°. The block is pushed along the surface till the spring compresses by 10 cm and then released from rest. (a) How much potential energy was stored in the block-spring-support system when the block was just released? (b) Determine the speed of the block when it crosses the point when the spring is neither compressed nor stretched. (c) Determine the position of the block where it just comes to rest on its way up the incline.

Ans: (a) 0.4 J. (b) 0.79 m/s. (c) 6.8 cm.

Ex 8.7.10. A block of mass 200 g is attached at the end of a massless spring of spring constant 100 N/cm. The other end of the spring is attached to the ceiling and the mass is brought to rest. Let us mark this point as O. Suppose, this point is taken to be the zero of the potential energy of the block, both from the weight and the spring force. The mass hangs freely and the spring is in a stretched state. The block is then pulled downward by another 5 cm and released from rest. (a) What is the net potential energy of the block at the instant the block is at the lowest point? (b) What is the net potential energy of the block at the instant the block returns to the point marked O? (c) What is the speed of the block as it crosses the point marked O? (d) How high above the point marked O does the block rise before coming to rest again?

(a) 12.4 J, (b) U = 0, (d) 11.1 m/s, (d) 4.96 cm.

Conservation of Energy Involving Universal Gravitational Force

Ex 8.7.11. Determine the escape speed of a projectile from the Moon.

Ans: 2,380 m/s.

Ex 8.7.12. Determine the escape speed of a projectile from the planet Jupiter.

Ans: 60,000 m/s.

Ex 8.7.13. A satellite of mass m is to be placed in a circular orbit of radius $2R_E$, where R_E is the radius of the Earth. With what speed with respect to the fixed center of the Earth should the satellite be launched from a point on the equator of the Earth?

Ans: 9200 m/s.

Ex 8.7.14. The Earth revolves around the Sun in an elliptical orbit with the Sun at one of the foci. In its orbit, the Earth makes a closest approach to the Sun, called the perihelion, and a farthest distance from the Sun, called the aphelion. The closest approach in the year 2000 took place on January 3, 2000 when the Earth-Sun distance was 1.46×10^{11} m and the farthest distance took place on July 4, 2000 with the Earth-Sun distance of 1.51×10^{11} m. Find the difference in the speed of Earth at the two locations.

Ans: $v_2 = \sqrt{\dfrac{2\left[U(r_2) - U(r_1)\right]\ r_1^2}{m(r_2^2 - r_1^2)}}, \quad (r_1 \neq r_2),\ v_1 r_1 = v_2 r_2.$

Ex 8.7.15. Suppose your friend claims to have discovered a mysterious force in nature that acts on all particles in the three-dimensional space. He tells you that the force is always pointed towards a definite point in space, which we can call the **force center**. The magnitude of the force turns out to be proportional to $1/r^3$, where r is the distance from the force center to any other point. Let b be the proportionality constant, i.e. the magnitude of the force on a particle can be written as b/r^3, when the particle is at a distance r from the force center. (a) Find the potential energy of a particle when it is at a distance D from the force center, assuming the potential energy to be zero when the particle is at infinity. (b) Explain why the reference of the potential energy cannot be chosen at the force center. (c) Formally, write the potential energy if the magnitude of the force is an arbitrary function $f(r)$?

Ans: (a) $-b/r^2$, (b) $U(0)$ not defined, (c) $U(r) = \int_{\text{ref}}^{r} f(r)dr$.

Nonconservation of Energy

Ex 8.7.16. In Exercise 8.7.5, the track was frictionless. Now, suppose 10% of the change in gravitational energy due to weight is lost due to friction. What will be the speeds at A, B, and C?

Ans: $v_A = 23$ m/s.

Ex 8.7.17. A sky diver exits an air plane at almost zero speed. He falls a distance of 50 m. His speed at that point is 10 m/s. Show calculations to decide if his energy is conserved or not.

Ans: Energy not conserved.

Ex 8.7.18. A hockey puck is shot across a iced pond. Before the hockey puck was hit the puck was at rest. After the hit, the puck has a speed of 40 m/s. The puck comes to rest after going a distance of 30 m. (a) Describe how the energy of the puck changes over time, giving the numerical values of any work or energy involved. (b) Find the magnitude of the net friction force.

Ans: (a) Loss of energy = 240 N.m, (b) $F = 8$ N.

Ex 8.7.19. A bottle rocket is shot straight up in the air with a speed 30 m/s. If the air resistance is ignored, the bottle would go up to a height of approximately 46 m. But, the rocket goes up to only 35 m before returning to the ground. What happened? Explain, giving numerical values of any work or energy involved.

Power

Ex 8.7.20. A crate is being pushed across a rough floor surface. If no force is applied on the crate, the crate will slow down and come to a stop. If the crate of mass 50 kg moving at speed 8 m/s comes to rest in 10 seconds, what is the rate at which the frictional force on the crate takes energy away from the crate?

Ans: 160 J/s.

Ex 8.7.21. In the exercise above, suppose that a horizontal force of 20 N in the direction of the velocity is required to maintain the speed of the crate constant at 8 m/s. (a) What is the power of this force? (a) Note that the acceleration of the crate is zero despite the fact that 20 N force acts on the crate horizontally. What happens to the energy given to the crate as a result of the work done by this 20-N force? Or, does this force do any work? Decide and give reason for your answer.

Ans: (a) 160 W.

Ex 8.7.22. Grains from a hopper falls at a rate of 10 kg/sec vertically onto a conveyor belt that is moving horizontally at a constant speed 2 m/s. (a) What force is needed to keep the conveyor belt moving at the constant velocity? (b) What is the minimum power of the motor driving the conveyor belt?

Ans: (a) 20 N; (b) 40 W.

Ex 8.7.23. A cyclist in a race must climb a 5° hill at a speed of 8 m/s. If the mass of the bike and the biker together is 80 kg, what must be the power output of the biker to achieve the goal?

Ans: 547 W.

Elastic Collision

Ex 8.7.24. An alpha particle (which is the nucleus of a Helium atom) of mass 4 u (1 u = 1.66×10^{-27} kg) at a speed of 1×10^4 m/s strikes a gold nucleus (m = 197 u) at rest head on and is repelled <u>elastically</u> backward. Find the final velocities of the alpha particle and the gold nucleus.

Ans: Speeds: 9,600 m/s and 392 m/s.

Ex 8.7.25. A billiard ball of mass m moving with speed 2 m/s strikes another billiard ball of the same mass at rest. After the collision, the incoming ball is deviated in the direction 15° from the original direction and moves with speed u while the struck ball is sent with speed w in the direction of 10° direction from the original direction of the first ball. (a) What are the speeds of the two balls after the collision? (b) Is the collision elastic? Why or why not.

Ans: (a) 0.82 m/s and 1.22 m/s; (b) not elastic.

Ex 8.7.26. A neutron (mass = 1 u, with u given in Exercise 8.7.24) moving at a speed of 3×10^5 m/s strikes a stationary hydrogen atom (mass = 1 u) head on. After the collision the stationary atom is found to move with a speed of 2×10^5 m/s in the direction of the neutron's original direction. (a) Find the velocity of the neutron after the collision. (b) Find the restitution and determine if the collision is elastic.

Ans: (a) 1×10^5 m/s, forward; (b) restitution = 1/3.

Ex 8.7.27. A particle of mass m moving at the speed v strikes head on another particle of mass $2m$ at rest in an elastic collision. Find the speeds of the two particles after the collision.

Ans: $1/3\ v$ and $2/3\ v$.

Ex 8.7.28. A particle of mass m ($= 1$ gram) moving with a speed v strikes a stationary particle of mass $2m$ head on. After the collision, the heavier particle breaks up into two parts of mass $0.5\ m$ and $1.5\ m$. The initial particle comes to rest as a result of the collision, but $0.5\ m$ particle moves in the direction of $30°$ from the original direction of m with a speed of $0.2\ v$. (a) What is the direction and speed of $1.5\ m$ particle after the collision. (b) Is the collision elastic? Why or why not.

Ans: (a) $0.61\ v$, $0.31°$, (b) not elastic.