Homework 3 Energy

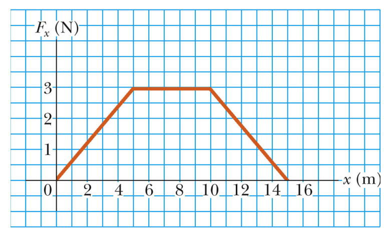
1. A block of mass 2.50 kg is pushed 2.20 m along a frictionless horizontal table by a constant 16.0-N force directed 25.0° below the horizontal. Determine the work done on the block by (a) the applied force, (b) the normal force exerted by the table, and (c) the gravitational force. (d) Determine the total work done on the block.

2. Batman, whose mass is 80.0 kg, is dangling on the free end of a 12.0-m rope, the other end of which is fixed to a tree limb above. He is able to get the rope in motion as only Batman knows how, eventually getting it to swing enough that he can reach a ledge when the rope makes a 60.0° angle with the vertical. How much work was done by the gravitational force on Batman in this maneuver?

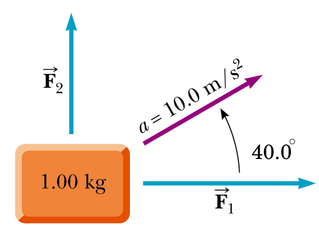
3. A force $\vec{F} = (6\hat{i} - 2\hat{j})\ N$ acts on a particle that undergoes a displacement $\Delta\vec{r} = (3\hat{i} + \hat{j})\ m$. What is (a) the work done by the force on the particle and (b) the angle θ between $\vec{F}$ and $\vec{\Delta}\vec{r}$.

4. The force acting on a particle is $\vec{F}_x = (8x - 16)\ N$, where x is in meters. (a) Make a plot of this force versus x from $x = 0$ to $x = 3.00\ m$. (b) From your graph, find the net work done by this force on the particle as it moves from $x = 0$ to $x = 3.00\ m$.

5. A particle is subject to a force $\vec{F}_x$ that varies with position as shown here. Find the work done by the force on the particle as it moves (a) from $x = 0$ to $x = 5.00\ m$, (b) from $x = 5.00\ m$ to $x = 10.0\ m$, and (c) from $x = 10.0\ m$ to $x = 15.0\ m$. (d) What is the total work done by the force over the distance $x = 0$ to $x = 15.0\ m$?

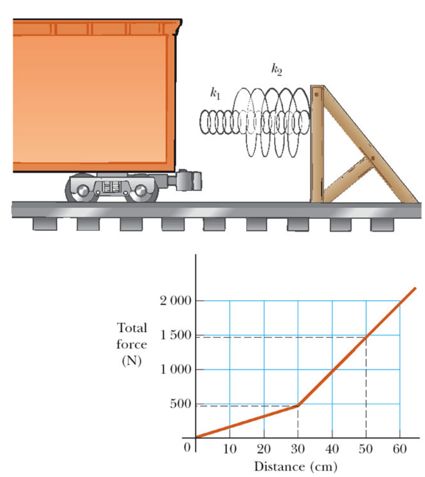


6. An object of mass $m = 1\ kg$ is observed to accelerate at $a = 10\ m/s^2$ in a direction $\theta = 40°$ north of east as shown in the figure. The force $\vec{F}_2$ acting on the object has a magnitude $|\vec{F}_2| = 6.4\ N$ and is directed north. What is the magnitude and direction of the force $\vec{F}_1$?



7. A 650-kg elevator starts from rest. It moves upward for 3.00 s with constant acceleration until it reaches its cruising speed of 1.75 m/s. (a) What is the average power of the elevator motor during this time interval? (b) How does this power compare with the motor power when the elevator moves at its cruising speed?

8. A $6000 - kg$ freight car rolls along rails with negligible friction. The car is brought to rest by a combination of two coiled springs as illustrated in the figure. Both springs obey Hookes law with $k_1 = 1600\ N/m$ and $k_2 = 3400\ N/m$. After the first spring compresses a distance of 30.0 cm, the second spring acts with the first to increase the force as additional compression occurs as shown in the graph. The car comes to rest 50.0 cm after first contacting the two-spring system. Find the cars initial speed.



9. You are asked to design bumpers for the walls of a parking garage. The specifications are that a 1200-kg car moving at 0.50 m/s can compress the bumper no more than 0.05 m before bringing the car to a halt. The bumpers obey Hooke's Law. (a) Sketch the force exerted by the bumper as its is compressed a distance x_1. Label the endpoints of your curve with their $x - y$ values in terms of x_1 and k the spring constant. (b) What is the work done by the bumper when it is compressed? Explain your answer using the figure you made above. (c) What is the required spring constant of the bumper?

10. An energy-efficient light bulb, taking in 28.0 W of power, can produce the same level of brightness as a conventional light bulb operating at power 100 W. The lifetime of the energy-efficient bulb is 10 000 h and its purchase price is \$17.0, whereas the conventional bulb has lifetime 750 h and costs \$0.420 per bulb. Determine the total savings obtained by using one energy-efficient bulb over its lifetime as opposed to using conventional bulbs over the same time interval. Assume an energy cost of \$0.080 0 per kilowatt-hour.

11. When a 4.00-kg object is hung vertically on a certain light spring that obeys Hookes law, the spring stretches 2.50 cm. If the 4.00-kg object is removed, (a) how far will the spring stretch if a 1.50-kg block is hung on it and (b) how much work must an external agent do to stretch the same spring 4.00 cm from its unstretched position?

12. It takes $W_0 = 5.0\ J$ of work to stretch a Hooke's-Law spring a distance $x = 0.1\ m$ from its unstressed length. What is the extra work W_1 required to stretch it an additional 0.12 m?

13. A force $\vec{F} = (4x\hat{i} + 3y\hat{j})\ N$ acts on an object as the object moves in the x direction from the origin to $x = 5.00\ m$. Find the work $W \int \vec{F} \cdot d\vec{r}$ done on the object by the force.

14. A 1.0 kg block is dropped onto a vertical spring with spring constant $k = 500.0\ N/m$. The block becomes attached to the spring and the spring compresses 0.15 m before momentarily stopping. What is the speed of the block just before impact?

15. In the sport of bungee jumping a person jumps from a bridge with her feet attached to an elastic cord hanging from the bridge as shown in the figure. The unstretched length of the cord is $l_c = 20\ m$, the person has a mass of $m = 58\ kg$ and a height of $h_p = 1.7\ m$ and the bridge is $h_b = 28\ m$ above the rocks below. The force constant of the bungee cord is $k = 500\ N/m$. Does the person survive the jump?

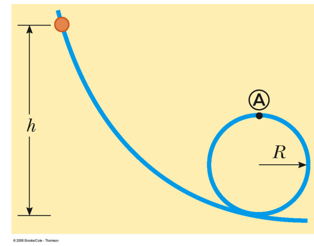
16. A $0.600 - kg$ particle has a speed of 2.00 m/s at point **A** and kinetic energy of 7.50 J at point **B**. (a) What is its kinetic energy at **A**? (b) What is its speed at **B**? (c) What is the total work done on the particle as it moves from **A** to **B**?

17. A $4.00 - kg$ particle is subject to a total force that varies with position as shown in the figure for Problem 5. The particle starts from rest at $x = 0$. What is its speed at (a) $x = 5.00\ m$, (b) $x = 10.0\ m$, and (c) $x = 15.0\ m$?

18. Use the chain rule and any other tools you know from calculus to differentiate the following functions.
(a) $f(x) = (2x^3 + 3x^{-1})^{45}$
(b) $f(x) = \sin(x^2 - 2x)$
(c) $f(x) = (x^4 + 1)^3/\sqrt{1 - 4x^3}$
(d) $f(x) = \cos^2(2x) + \sin(x^2)$
(e) $f(x) = 1/(5x + e^{-2x})$

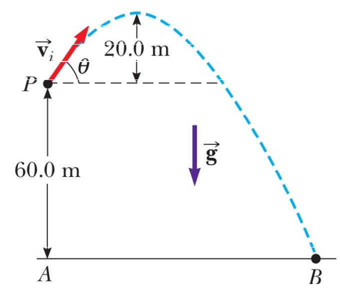
19. You can think of the work kinetic energy theorem as a second theory of motion, parallel to Newtons laws in describing how outside influences affect the motion of an object. In this problem, do parts (a) and (b) separately from parts (c) and (d) to compare the predictions of the two theories. In a rifle barrel, a $15.0 - g$ bullet is accelerated from rest to a speed of 780 m/s. (a) Find the work that is done on the bullet. (b) Assuming that the rifle barrel is 72.0 cm long, find the magnitude of the average total force that acted on it as $F = W/(\Delta r \cos\theta)$. (c) Find the constant acceleration of a bullet that starts from rest and gains a speed of 780 m/s over a distance of 72.0 cm. (d) Assuming that the bullet has mass 15.0 g, find the total force that acted on it as $\sum F = ma$.

20. A bead slides without friction around a loop-the-loop (see the figure). The bead is released from a height $h = 3.50R$. (a) What is its speed at point **A**? (b) How large is the normal force on it if its mass is 5.00 g?

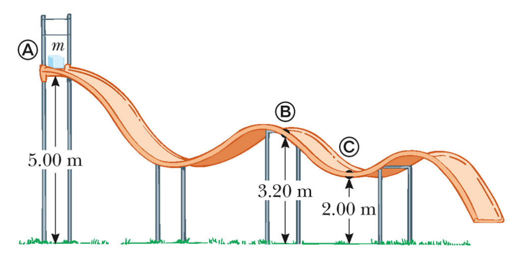


21. A $400 - N$ child is in a swing that is attached to ropes 2.00 m long. Find the gravitational potential energy of the child Earth system relative to the childs lowest position when (a) the ropes are horizontal, (b) the ropes make a 30.0° angle with the vertical, and (c) the child is at the bottom of the circular arc.

22. A particle of mass 0.500 kg is fired from point P as shown below. The particle has an initial velocity v_i with a horizontal component of 30.0 m/s. The particle rises to a maximum height of 20.0 m above P. Using the law of conservation of energy, determine (a) the vertical component of $\vec{v}_i$, (b) the work done by the gravitational force on the particle during its motion from P to B, and (c) the horizontal and the vertical components of the velocity vector when the particle reaches B.

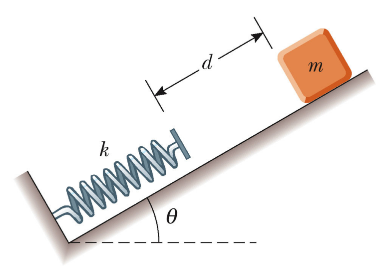


23. A particle of mass $m = 5.00$ kg is released from point A and slides on the frictionless track shown below. Determine (a) the particles speed at points B and C and (b) the net work done by the gravitational force as the particle moves from A to C.



24. A simple pendulum consists of an object suspended by a string. The object is assumed to be a particle. The string, with its top end fixed, has negligible mass and does not stretch. In the absence of air friction, the system oscillates by swinging back and forth in a vertical plane. The string is 2.00 m long and makes an initial angle of 30.0° with the vertical. Calculate the speed of the particle (a) at the lowest point in its trajectory and (b) when the angle is 15.0°.

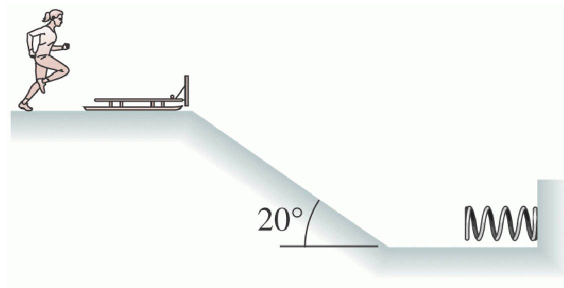
25. An object of mass m starts from rest and slides a distance d down a frictionless incline of angle θ. While sliding, it contacts an unstressed spring of negligible mass as shown in the figure. The object slides an additional distance x as it is brought momentarily to rest by compression of the spring (of force constant k). Find the initial separation d between the object and the spring.



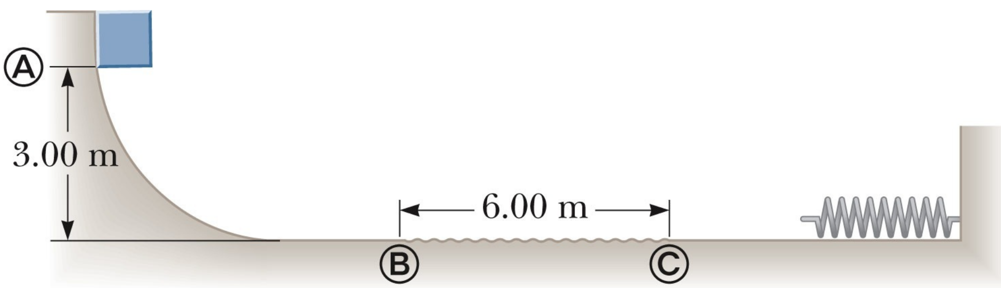
26. in 2000, the NASA misson NEAR Shoemaker was placed in orbit around an asteroid. Consider a spherical asteroid of mass $m = 10^{16}$ kg and a radius $R = 8.8$ km. (a) What is the spacecraft's speed if it orbits a height $h = 5$ km above the surface? (b) What is the escape speed from the asteroid if an object is launched from the surface?

27. At the Earths surface, a projectile is launched straight up at a speed of 10.0 km/s. To what height will it rise? Ignore air resistance.

28. A new event has been proposed for the Winter Olympics. An athlete will sprint a distance $x_1 = 100\ m$, starting from rest, and leap into a bobsled of mass $m_b = 20\ kg$. The person and the bobsled will slide down a ice-covered ramp of length $l_r = 50\ m$ and tilted at an angle $\theta_r = 20°$ to the horizontal. At the bottom of the slope awaits a spring with spring constant $k = 2000\ N/m$. The athlete who compresses the spring the most wins. The US entry in the competition Lisa has a mass $m_L = 40\ kg$ and she can reach a maximum velocity $v_L = 12\ m/s$ in the 100-m dash. How far will Lisa compress the spring? Ignore any friction with the ice.



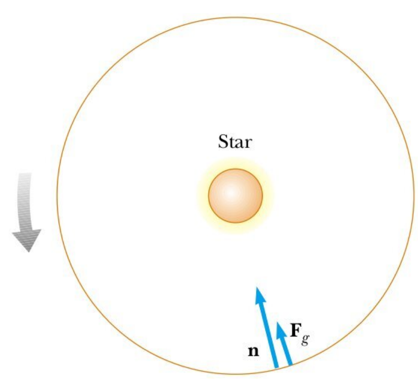
29. A block of mass $m = 10\ kg$ is released from point **A** in the figure. The track is frictionless except for a rough surface in the region between points **B** and **C** of length $L = 6\ m$ where the block will lose some of its mechanical energy due to the work done by friction when it slides through. The block is released from rest and slides down the track, passes through the rough surface, and eventually hits the spring (force constant $k = 2.25 \times 10^3\ N/m$). The block compresses the spring a distance $x_s = 0.3\ m$ from it's equilibrium position before momentarily coming to rest. What is the coefficient of kinetic friction between the block and the rough surface between points **B** and **C**?



30. Ball 1, with a mass of 100 g and traveling at 10 m/s, collides head-on with ball 2, which has a mass of 300 g and is initially at rest. What is the final velocity of each ball if the collision is (a) perfectly elastic? (b) perfectly inelastic?

31. A satellite orbiting the Earth has a mass $m = 100\ kg$ and a height $h = 2.0 \times 10^6\ m$. (a) What is the potential energy of the satellite-Earth system? (b) What is the magnitude of the gravitational force exerted by the Earth on the satellite? (c) What force does the satellite exert on the Earth?

32. In author Larry Niven's epic sci-fi novel *Ringworld*, a huge ring rotates about a star and is home to a branch of humanity. The tangential speed of the ring is $v = 1.25 \times 10^6\ m/s$, and its radius is $R = 1.53 \times 10^{11}\ m$. (a) What is the centripetal acceleration of the inhabitants?(b) The inhabitants of this ring world live on the starlit inner surface of the ring. Each person experiences a normal contact force $\vec{N}$. By itself, this normal force produces a centripetal acceleration $a_N = 9.90\ m/s^2$. The star at the center of the ring exerts a gravitational force on the ring and its inhabitants. The difference between the total acceleration and the acceleration provided by the normal force is due to the gravitational attraction of the central star. Show that the mass of the star is approximately $m_s = 10^{32}\ kg$.



33. A satellite of mass $m = 200\ kg$ is parked in Earth orbit at a height $h = 200\ km$ above the surface. (a) The satellite has a circular orbit so how long does the satellite take to complete one orbit? (b) What is the satellites speed? (c) What is the minimum energy input necessary to place this satellite in orbit? Ignore air resistance but include the effect of the planets daily rotation.

34. A satellite of mass $m = 200\ kg$ is parked in a circular, Earth orbit at a height $h = 1000\ km$ above the surface. What is the minimum additional velocity that must be imparted to the satellite to escape the Earth's gravity?

35. Use the definition of the derivative $dy/dx = \lim_{\Delta x \to 0} \Delta y/\Delta x$ to calculate the derivative of $y = 1/x$.