# Bouncing Ball Problem (10 Points)

## Problem Statement

In this exercise, we will analyze the following scenario: A ball is held at a height of 1 meter above the ground and is released. After each bounce, the ball's speed decreases by a factor of 0.9.

(a) Derive a formula for the speed of the ball immediately after the $n$-th bounce. Express your result in terms of the initial height and the given reduction factor. (2 points)

(b) Determine an analytical expression for the maximum height reached by the ball after the $n$-th bounce. (2 points)

(c) Compute a formula for the total time elapsed from the moment the ball is released until it makes its $(n+1)$-th impact with the ground. (3 points)

(d) Represent the above quantities graphically as functions of the number of bounces. Provide a brief discussion of the results. (3 points)

**Deadline:** February 20, 2025.

Week 1. Problems for class:

**10.** (a) Assume the equation $x = At^3 + Bt$ describes the motion of a particular object, with $x$ having the dimension of length and $t$ having the dimension of time. Determine the dimensions of the constants $A$ and $B$. (b) Determine the dimensions of the derivative $dx/dt = 3At^2 + B$.

**17.** (a) Compute the order of magnitude of the mass of a bathtub half full of water. (b) Compute the order of magnitude of the mass of a bathtub half full of copper coins.

**20.** V How many significant figures are in the following numbers? (a) $78.9 \pm 0.2$ (b) $3.788 \times 10^9$ (c) $2.46 \times 10^{-6}$ (d) 0.005 3

**39.** S A woman stands at a horizontal distance $x$ from a mountain and measures the angle of elevation of the mountaintop above the horizontal as $\theta$. After walking a distance $d$ closer to the mountain on level ground, she finds the angle to be $\phi$. Find a general equation for the height $y$ of the mountain in terms of $d$, $\phi$, and $\theta$, neglecting the height of her eyes above the ground.

**7.** T A person takes a trip, driving with a constant speed of 89.5 km/h, except for a 22.0-min rest stop. If the person's average speed is 77.8 km/h, (a) how much time is spent on the trip and (b) how far does the person travel?

**10.** (a) Use the data in Problem 3 to construct a smooth graph of position versus time. (b) By constructing tangents to the $x(t)$ curve, find the instantaneous velocity of the car at several instants. (c) Plot the instantaneous velocity versus time and, from this information, determine the average acceleration of the car. (d) What was the initial velocity of the car?

| | | | | | | |
|---|---|---|---|---|---|---|
| **$t$ (s)** | 0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 |
| **$x$ (m)** | 0 | 2.3 | 9.2 | 20.7 | 36.8 | 57.5 |

**32.** A student drives a moped along a straight road as described by the velocity–time graph in Figure P2.32. Sketch this graph in the middle of a sheet of graph paper. (a) Directly above your graph, sketch a graph of the position versus time, aligning the time coordinates of the two graphs. (b) Sketch a graph of the acceleration versus time directly below the velocity–time graph, again aligning the time coordinates. On each graph, show the numerical values of $x$ and $a_x$ for all points of inflection. (c) What is the acceleration at $t$ = 6.00 s? (d) Find the position (relative to the starting point) at $t$ = 6.00 s. (e) What is the moped's final position at $t$ = 9.00 s?

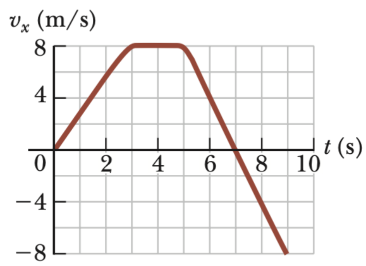


**Figure P2.32**

**42.** Two thin rods are fastened to the inside of a circular ring as shown in Figure P2.42. One rod of length $D$ is vertical, and the other of length $L$ makes an angle $\theta$ with the horizontal. The two rods and the ring lie in a vertical plane. Two small beads are free to slide without friction along the rods. (a) If the two beads are released from rest simultaneously from the positions shown, use your intuition and guess which bead reaches the bottom first. (b) Find an expression for the time interval required for the red bead to fall from point Ⓐ to point Ⓒ in terms of $g$ and $D$. (c) Find an expression for the time interval required for the blue bead to slide from point Ⓑ to point Ⓒ in terms of $g$, $L$, and $\theta$. (d) Show that the two time intervals found in parts (b) and (c) are equal. *Hint:* What is the angle between the chords of the circle Ⓐ Ⓑ and Ⓑ Ⓒ? (e) Do these results surprise you? Was your intuitive guess in part (a) correct? This problem was inspired by an article by Thomas B. Greenslade, Jr., "Galileo's Paradox," *Phys. Teach.* **46**, 294 (May 2008).

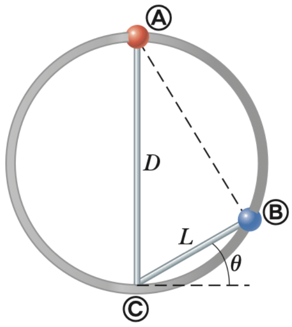


**Figure P2.42**

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Problems for practice at home:

**36.** A woman is reported to have fallen 144 ft from the 17th floor of a building, landing on a metal ventilator box that she crushed to a depth of 18.0 in. She suffered only minor injuries. Ignoring air resistance, calculate (a) the speed of the woman just before she collided with the ventilator and (b) her average acceleration while in contact with the box. (c) Modeling her acceleration as constant, calculate the time interval it took to crush the box.

[(a) 29.3m/s, (b) –96.0g, (c) $3.13\times10^{-2}$s]

**41.** Lisa rushes down onto a subway platform to find her train already departing. She stops and watches the cars go by. Each car is 8.60 m long. The first moves past her in 1.50 s and the second in 1.10 s. Find the constant acceleration of the train.

[1.60m/s$^2$]

# Projectile Motion on an Incline (10 Points)

## Problem Statement

Consider a projectile launched up an inclined plane, where the plane is inclined at an angle $\phi$ and the projectile is fired with initial speed $v_i$ at an angle $\theta_i$ above the horizontal ($\theta_i > \phi$).

(a) Establish a suitable coordinate system and derive the equation of the projectile's trajectory in this coordinate system. (4 points)

(b) In the chosen coordinate system, write down the equation representing the inclined plane. (1 point)

(c) Determine the condition under which the projectile intersects the inclined plane. Provide an equation that describes this condition. (1 point)

(d) By performing the necessary algebraic manipulations, show that the projectile travels a distance $d$ up the incline, given by:

$$d = \frac{2\, v_i^2\, \cos(\theta_i)\, \sin(\theta_i - \phi)}{g\, \cos^2(\phi)}.$$

(1 points)

(e) If the initial speed $v_i$ is held constant and $\theta_i$ is varied, at which angle $\theta_i$ is the distance $d$ maximized? (3 points)

**Deadline:** February 27, 2025.

Week 2. Problems for class:

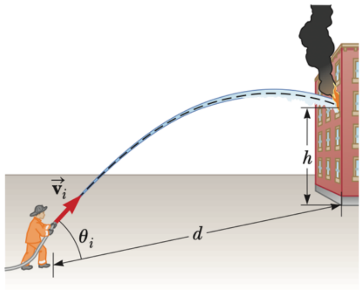

Figure P4.11

**11.** S A firefighter, a distance $d$ from a burning building, directs a stream of water from a fire hose at angle $\theta_i$ above the horizontal as shown in Figure P4.11. If the initial speed of the stream is $v_i$, at what height $h$ does the water strike the building?

**23.** (a) Can a particle moving with instantaneous speed 3.00 m/s on a path with radius of curvature 2.00 m have an acceleration of magnitude 6.00 m/s²? (b) Can it have an acceleration of magnitude 4.00 m/s²? In each case, if the answer is yes, explain how it can happen; if the answer is no, explain why not.

**29.** AMT T A science student is riding on a flatcar of a train traveling along a straight, horizontal track at a constant speed of 10.0 m/s. The student throws a ball into the air along a path that he judges to make an initial angle of 60.0° with the horizontal and to be in line with the track. The student's professor, who is standing on the ground nearby, observes the ball to rise vertically. How high does she see the ball rise?

**50.** A projectile is fired up an incline (incline angle $\phi$) with an initial speed $v_i$ at an angle $\theta_i$ with respect to the horizontal ($\theta_i > \phi$) as shown in Figure P4.50. (a) Show that the projectile travels a distance $d$ up the incline, where

$$d = \frac{2v_i^{\,2}\cos\theta_i\sin(\theta_i - \phi)}{g\cos^2\phi}$$

**25.** S An object of mass $m_1$ hangs from a string that passes over a very light fixed pulley $P_1$ as shown in Figure P5.25. The string connects to a second very light pulley $P_2$. A second string passes around this pulley with one end attached to a wall and the other to an object of mass $m_2$ on a frictionless, horizontal table. (a) If $a_1$ and $a_2$ are the accelerations of $m_1$ and $m_2$, respectively, what is the relation between these accelerations? Find expressions for (b) the tensions in the strings and (c) the accelerations $a_1$ and $a_2$ in terms of the masses $m_1$ and $m_2$, and $g$.

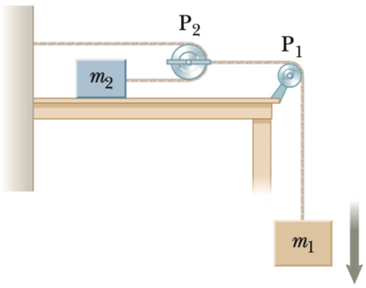

Figure P5.25

**36.** A 5.00-kg block is placed on top of a 10.0-kg block (Fig. P5.36). A horizontal force of 45.0 N is applied to the 10-kg block, and the 5.00-kg block is tied to the wall. The coefficient of kinetic friction between all moving surfaces is 0.200. (a) Draw a free-body diagram for each block and identify the action–reaction forces between the blocks. (b) Determine the tension in the string and the magnitude of the acceleration of the 10.0-kg block.

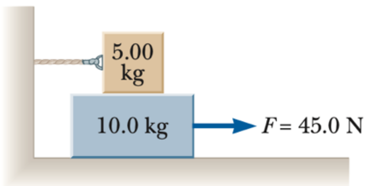

Figure P5.36

**53.** **S** Initially, the system of objects shown in Figure P5.49 is held motionless. The pulley and all surfaces and wheels are frictionless. Let the force $\vec{\mathbf{F}}$ be zero and assume that $m_1$ can move only vertically. At the instant after the system of objects is released, find (a) the tension $T$ in the string, (b) the acceleration of $m_2$, (c) the acceleration of $M$, and (d) the acceleration of $m_1$. (*Note:* The pulley accelerates along with the cart.)

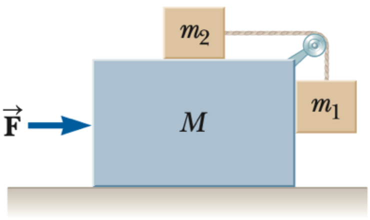


**Figure P5.49** Problems 49 and 53

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Problems for practice at home:

**36.** A particle starts from the origin with velocity $5\hat{\mathbf{i}}$ m/s at $t = 0$ and moves in the $xy$ plane with a varying acceleration given by $\vec{\mathbf{a}} = (6\sqrt{t}\,\hat{\mathbf{j}})$, where $\vec{\mathbf{a}}$ is in meters per second squared and $t$ is in seconds. (a) Determine the velocity of the particle as a function of time. (b) Determine the position of the particle as a function of time.

[(a) $(5\mathbf{i}+4t^{3/2}\mathbf{j})$m/s, (b) $(5t\mathbf{i}+1.6t^{5/2}\mathbf{j})$m]

**45.** **S** A crate of weight $F_g$ is pushed by a force $\vec{\mathbf{P}}$ on a horizontal floor as shown in Figure P5.45. The coefficient of static friction is $\mu_s$, and $\vec{\mathbf{P}}$ is directed at angle $\theta$ below the horizontal. (a) Show that the minimum value of $P$ that will move the crate is given by

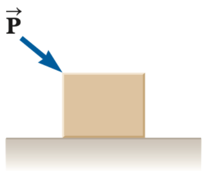


**Figure P5.45**

$$P = \frac{\mu_s F_g \sec\theta}{1 - \mu_s \tan\theta}$$

(b) Find the condition on $\theta$ in terms of $\mu_s$ for which motion of the crate is impossible for any value of $P$.

# Dynamics of a Wedge System

## Problem Statement

Consider the mechanical system depicted in the figure below. The system consists of:

- A lower wedge of mass $M$.
- An upper wedge of mass $m$.
- An object resting on the upper wedge, also of mass $m$.

The angle of the inclined surface is $\alpha = 45°$. All surfaces are frictionless, and the acceleration due to gravity is $g$.

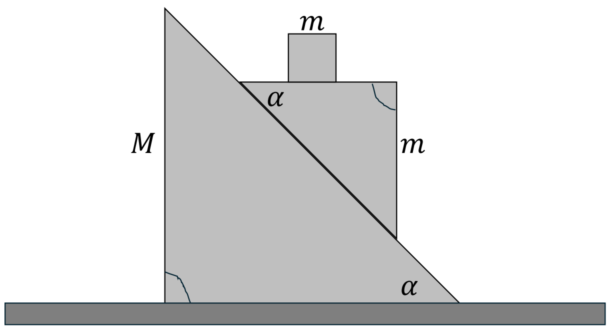


Figure 1: Schematic representation of the wedge system.

## Tasks

1. Perform a force analysis for each component of the system. Draw a free-body diagram illustrating all forces acting on the wedges and the object. **(2 points)**

2. Formulate the equations of motion for the system. **(2 points)**

3. Establish the relationship between the accelerations of the masses. Derive the necessary equation(s). *Hint: Consider the geometrical constraints and draw an auxiliary diagram to aid in the motion analysis.* **(3 points)**

4. Solve the system of linear equations to determine the accelerations of the masses in terms of the given parameters. **(3 points)**

**Note:** You may *alternatively* choose to analyze the problem using an accelerated frame of reference. If so, you can follow the same steps outlined above while considering the appropriate fictitious forces and constraints.

**Submission Deadline:** March 6, 2025.

Week 3. Problems for class:

**10.** T A 40.0-kg child swings in a swing supported by two chains, each 3.00 m long. The tension in each chain at the lowest point is 350 N. Find (a) the child's speed at the lowest point and (b) the force exerted by the seat on the child at the lowest point. (Ignore the mass of the seat.)

**22.** S Assume the resistive force acting on a speed skater is proportional to the square of the skater's speed $v$ and is given by $f = -kmv^2$, where $k$ is a constant and $m$ is the skater's mass. The skater crosses the finish line of a straight-line race with speed $v_i$ and then slows down by coasting on his skates. Show that the skater's speed at any time $t$ after crossing the finish line is $v(t) = v_i/(1 + ktv_i)$.

**49.** Because of the Earth's rotation, a plumb bob does not hang exactly along a line directed to the center of the Earth. How much does the plumb bob deviate from a radial line at 35.0° north latitude? Assume the Earth is spherical.

**15.** S 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 illustrated in Figure P7.15. (a) Assuming the particle moves at a constant speed, show that $F = mg\cos\theta$. *Note:* If the particle moves at constant speed, the component of its acceleration tangent to the cylinder must be zero at all times. (b) By directly integrating $W = \int \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}}$, find the work done in moving the particle at constant speed from the bottom to the top of the half-cylinder.

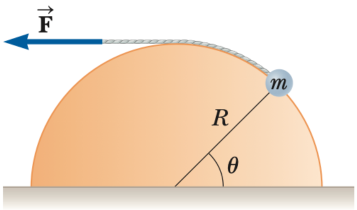


**Figure P7.15**

**28.** **Review.** A 7.80-g bullet moving at 575 m/s strikes the hand of a superhero, causing the hand to move 5.50 cm in the direction of the bullet's velocity before stopping. (a) Use work and energy considerations to find the average force that stops the bullet. (b) Assuming the force is constant, determine how much time elapses between the moment the bullet strikes the hand and the moment it stops moving.

**38.** For the potential energy curve shown in Figure P7.38, (a) determine whether the force $F_x$ is positive, negative, or zero at the five points indicated. (b) Indicate points of stable, unstable, and neutral equilibrium. (c) Sketch the curve for $F_x$ versus $x$ from $x = 0$ to $x = 9.5$ m.

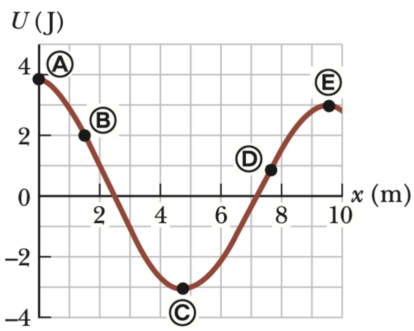


**Figure P7.38**

Problem Statement: Accelerating Frame of Reference

Revisit Problem 53 from Week 2, this time analyzing it within an accelerating frame of reference. Assume that the applied force F is nonzero (i.e. F>0).

Determine the magnitude of F required to ensure that the smaller blocks remain stationary relative to the larger block M.

**47.** An inclined plane of angle $\theta = 20.0°$ has a spring of force constant $k = 500$ N/m fastened securely at the bottom so that the spring is parallel to the surface as shown in Figure P7.47. A block of mass $m = 2.50$ kg is placed on the plane at a distance $d = 0.300$ m from the spring. From this position, the block is projected downward toward the spring with speed $v = 0.750$ m/s. By what distance is the spring compressed when the block momentarily comes to rest?

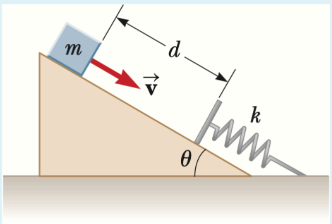


**Figure P7.47**
Problems 47 and 48.

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Problems for practice at home:

**36.** S A truck is moving with constant acceleration $a$ up a hill that makes an angle $\phi$ with the horizontal as in Figure P6.36. A small sphere of mass $m$ is suspended from the ceiling of the truck by a light cord. If the pendulum makes a constant angle $\theta$ with the perpendicular to the ceiling, what is $a$?

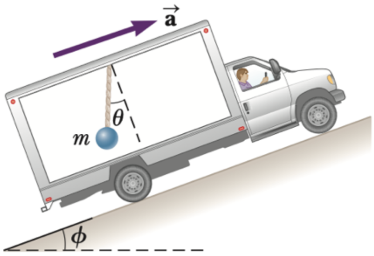



**Figure P6.36**

[g(cosϕ tanθ – sinϕ)]

**46.** Q|C (a) Take $U = 5$ for a system with a particle at position $x = 0$ and calculate the potential energy of the system as a function of the particle position $x$. The force on the particle is given by $(8e^{-2x})\,\hat{\mathbf{i}}$. (b) Explain whether the force is conservative or nonconservative and how you can tell.

[(a) $1+4e^{-2x}$]

# Bungee Jumping: A Physics Exploration

## Problem Statement

Starting from rest, a person of mass $m$ bungee jumps from a tethered hot-air balloon of height $h$ above the ground. The bungee cord has negligible mass and unstretched length $l_0$. One end is tied to the basket of the balloon and the other end to a harness around the person's body. The cord is modeled as a spring that obeys Hooke's law with a spring constant of k, and the person's body is modeled as a particle. The hot-air balloon does not move.

**Hint:** You are encouraged to introduce appropriate notation, such as defining $y_0 = \frac{mg}{k}$ or any other relevant parameters, to make your parametric calculations more concise.

(a) Express the gravitational potential energy of the person–Earth system as a function of the person's variable height $y$ above the ground. (1 point)

(b) Express the elastic potential energy of the cord as a function of $y$. (1 point)

(c) Express the total potential energy of the person–cord–Earth system as a function of $y$. (1 point)

(d) Plot a graph of the gravitational, elastic, and total potential energies as functions of $y$. (2 point)

(e) Assume air resistance is negligible. Determine the minimum height of the person above the ground during his plunge. (2 point)

(f) Does the potential energy graph show any equilibrium position or positions? If so, at what elevations? Are they stable or unstable? Explain your answer! (2 point)

(g) Determine the jumper's maximum speed. (1 point)

**Submission Deadline:** March 13, 2025.

Week 4. Problems for class:

**8.** A 40.0-kg box initially at rest is pushed 5.00 m along a rough, horizontal floor with a constant applied horizontal force of 130 N. The coefficient of friction between box and floor is 0.300. Find (a) the work done by the applied force, (b) the increase in internal energy in the box–floor system as a result of friction, (c) the work done by the normal force, (d) the work done by the gravitational force, (e) the change in kinetic energy of the box, and (f) the final speed of the box.

**16.** Q|C The electric motor of a model train accelerates the train from rest to 0.620 m/s in 21.0 ms. The total mass of the train is 875 g. (a) Find the minimum power delivered to the train by electrical transmission from the metal rails during the acceleration. (b) Why is it the minimum power?

**26.** Q|C **Review.** As shown in Figure P8.26, 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. The hanging block $m_2$ stops without bouncing when it strikes the floor. Consider the two blocks plus the Earth as the system. (a) Find the speed at which $m_1$ leaves the edge of the table. (b) Find the impact speed of $m_1$ on the floor. (c) What is the shortest length of the string so that it does not go taut while $m_1$ 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? (e) Why or why not?

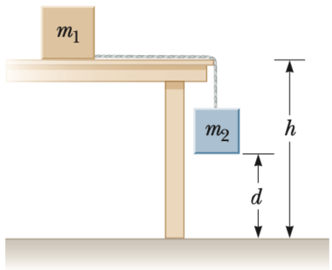



Figure P8.26

**40.** S A pendulum, comprising a light string of length $L$ and a small sphere, swings in the vertical plane. The string hits a peg located a distance $d$ below the point of suspension (Fig. P8.40). (a) Show that if the sphere is released from a height below that of the peg, it will return to this height after the string strikes the peg. (b) Show that if the pendulum is released from rest at the horizontal position ($\theta = 90°$) and is to swing in a complete circle centered on the peg, the minimum value of $d$ must be $3L/5$.

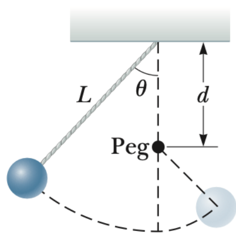
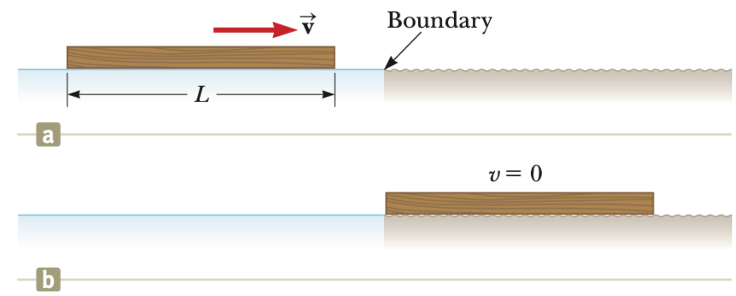



Figure P8.40

**41.** S A ball whirls around in a *vertical* circle at the end of a string. The other end of the string is fixed at the center of the circle. Assuming the total energy of the ball–Earth system remains constant, show that the tension in the string at the bottom is greater than the tension at the top by six times the ball's weight.

**44.** Q|C Starting from rest, a 64.0-kg person bungee jumps from a tethered hot-air balloon 65.0 m above the ground. The bungee cord has negligible mass and unstretched length 25.8 m. One end is tied to the basket of the balloon and the other end to a harness around the person's body. The cord is modeled as a spring that obeys Hooke's law with a spring constant of 81.0 N/m, and the person's body is modeled as a particle. The hot-air balloon does not move. (a) Express the gravitational potential energy of the person–Earth system as a function of the person's variable height $y$ above the ground. (b) Express the elastic potential energy of the cord as a function of $y$. (c) Express the total potential energy of the person–cord–Earth system as a function of $y$. (d) Plot a graph of the gravitational, elastic, and total potential energies as functions of $y$. (e) Assume air resistance is negligible. Determine the minimum height of the person above the ground during his plunge. (f) Does the potential energy graph show any equilibrium position or positions? If so, at what elevations? Are they stable or unstable? (g) Determine the jumper's maximum speed.

**45.** S **Review.** A uniform board of length $L$ is sliding along a smooth, frictionless, horizontal plane as shown in Figure P8.45a. The board then slides across the boundary with a rough horizontal surface. The coefficient of kinetic friction between the board and the second surface is $\mu_k$. (a) Find the acceleration of the board at the moment its front end has traveled a distance $x$ beyond the boundary. (b) The board stops at the moment its back end reaches the boundary as shown in Figure P8.45b. Find the initial speed $v$ of the board.

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Problems for practice at home:

**9.** A smooth circular hoop with a radius of 0.500 m is placed flat on the floor. A 0.400-kg particle slides around the inside edge of the hoop. The particle is given an initial speed of 8.00 m/s. After one revolution, its speed has dropped to 6.00 m/s because of friction with the floor. (a) Find the energy transformed from mechanical to internal in the particle–hoop–floor system as a result of friction in one revolution. (b) What is the total number of revolutions the particle makes before stopping? Assume the friction force remains constant during the entire motion.

[(a) 5.60J, (b) 2.28 revolutions]

**32.** QIC S As it plows a parking lot, a snowplow pushes an ever-growing pile of snow in front of it. Suppose a car moving through the air is similarly modeled as a cylinder of area $A$ pushing a growing disk of air in front of it. The originally stationary air is set into motion at the constant speed $v$ of the cylinder as shown in Figure P8.32. In a time interval $\Delta t$, a new disk of air of mass $\Delta m$ must be moved a distance $v\ \Delta t$ and hence must be given a kinetic energy $\frac{1}{2}(\Delta m)v^2$. Using this model, show that the car's power loss owing to air resistance is $\frac{1}{2}\rho A v^3$ and that the resistive force acting on the car is $\frac{1}{2}\rho A v^2$, where $\rho$ is the density of air. Compare this result with the empirical expression $\frac{1}{2}D\rho A v^2$ for the resistive force.

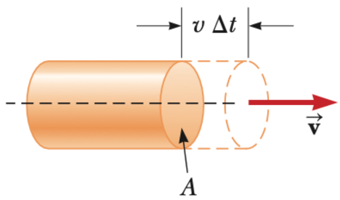

**Figure P8.32**

Week 5. Problems for class:

**23.** S A proton, moving with a velocity of $v_i\hat{\mathbf{i}}$, collides elastically with another proton that is initially at rest. Assuming that the two protons have equal speeds after the collision, find (a) the speed of each proton after the collision in terms of $v_i$ and (b) the direction of the velocity vectors after the collision.

**24.** V A uniform piece of sheet metal is shaped as shown in Figure P9.24. Compute the $x$ and $y$ coordinates of the center of mass of the piece.

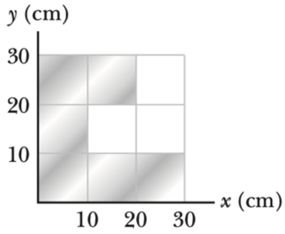

Figure P9.24

**28.** The vector position of a 3.50-g particle moving in the $xy$ plane varies in time according to $\vec{\mathbf{r}}_1 = (3\hat{\mathbf{i}} + 3\hat{\mathbf{j}})t + 2\hat{\mathbf{j}}t^2$, where $t$ is in seconds and $\vec{\mathbf{r}}$ is in centimeters. At the same time, the vector position of a 5.50 g particle varies as $\vec{\mathbf{r}}_2 = 3\hat{\mathbf{i}} - 2\hat{\mathbf{i}}t^2 - 6\hat{\mathbf{j}}t$. At $t = 2.50$ s, determine (a) the vector position of the center of mass of the system, (b) the linear momentum of the system, (c) the velocity of the center of mass, (d) the acceleration of the center of mass, and (e) the net force exerted on the two-particle system.

**33.** Q|C A rocket for use in deep space is to be capable of boosting a total load (payload plus rocket frame and engine) of 3.00 metric tons to a speed of 10 000 m/s. (a) It has an engine and fuel designed to produce an exhaust speed of 2 000 m/s. How much fuel plus oxidizer is required? (b) If a different fuel and engine design could give an exhaust speed of 5 000 m/s, what amount of fuel and oxidizer would be required for the same task? (c) Noting that the exhaust speed in part (b) is 2.50 times higher than that in part (a), explain why the required fuel mass is not simply smaller by a factor of 2.50.

**52.** Q|C Sand from a stationary hopper falls onto a moving conveyor belt at the rate of 5.00 kg/s as shown in Figure P9.52. The conveyor belt is supported by frictionless rollers and moves at a constant speed of $v = 0.750$ m/s under the action of a constant horizontal external force $\vec{\mathbf{F}}_{ext}$ supplied by the motor that drives the belt. Find (a) the sand's rate of change of momentum in the horizontal direction, (b) the force of friction exerted by the belt on the sand, (c) the external force $\vec{\mathbf{F}}_{ext}$, (d) the work done by $\vec{\mathbf{F}}_{ext}$ in 1 s, and (e) the kinetic energy acquired by the falling sand each second due to the change in its horizontal motion. (f) Why are the answers to parts (d) and (e) different?

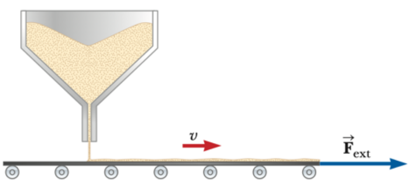

Figure P9.52

**53.** Two particles with masses $m$ and $3m$ are moving toward each other along the $x$ axis with the same initial speeds $v_i$. Particle $m$ is traveling to the left, and particle $3m$ is traveling to the right. They undergo an elastic glancing collision such that particle $m$ is moving in the negative $y$ direction after the collision at a right angle from its initial direction. (a) Find the final speeds of the two particles in terms of $v_i$. (b) What is the angle $\theta$ at which the particle $3m$ is scattered?

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Problems for practice at home:

**26.** A rod of length 30.0 cm has linear density (mass per length) given by

$$\lambda = 50.0 + 20.0x$$

where $x$ is the distance from one end, measured in meters, and $\lambda$ is in grams/meter. (a) What is the mass of the rod? (b) How far from the $x = 0$ end is its center of mass?

[(a) 15.9g, (b) 0.153m]

**41.** **S** Two gliders are set in motion on a horizontal air track. A light spring of force constant $k$ is attached to the back end of the second glider. As shown in Figure P9.41, the first glider, of mass $m_1$, moves to the right with speed $v_1$, and the second glider, of mass $m_2$, moves more slowly to the right with speed $v_2$. When $m_1$ collides with the spring attached to $m_2$, the spring compresses by a distance $x_{max}$, and the gliders then move apart again. In terms of $v_1$, $v_2$, $m_1$, $m_2$, and $k$, find (a) the speed $v$ at maximum compression, (b) the maximum compression $x_{max}$, and (c) the velocity of each glider after $m_1$ has lost contact with the spring.

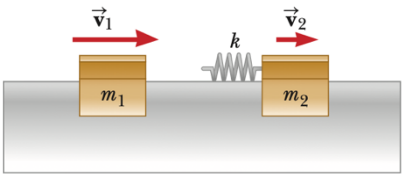

Figure P9.41

[(a) $\frac{m_1v_1+m_2v_2}{m_1+m_2}$, (b) $(v_1 - v_2)\sqrt{\frac{m_1m_2}{k(m_1+m_2)}}$, (c) $\frac{2m_1v_1+(m_2-m_1)v_2}{m_1+m_2}$,...]