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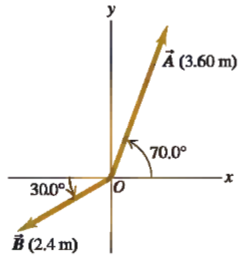
Chapter 1

Problem 49, 51, 86, 89, 93, 95, 96, 102.

1.49 (a) Write each vector in Fig. 1.37 in terms of the unit vectors $\hat{\imath}$ and $\hat{\jmath}$. (b) Use unit vectors to express the vector$\vec{C}$, where $\vec{C} = 3\vec{A} - 4\vec{B}$. (c) Find the magnitude and direction of $\vec{C}$.

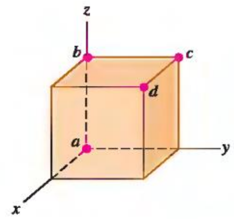


1.51 (a) Is the vector $(\hat{\imath} + \hat{\jmath} + \hat{k})$ a unit vector? Justify your answer. (b) Can a unit vector have any components with magnitude greater than unity? Can it have any negative components? In each case, justify your answer. (c) If $\vec{A} = a(3\hat{\imath} + 4\hat{\jmath})$, where a is a constant, determine the value of a that makes $\vec{A}$ a unit vector.

1.86 For the two vectors $\vec{A}$ and $\vec{B}$ in Fig. 1.37, (a) find the scalar product $\vec{A} \cdot \vec{B}$, and (b) find the magnitude and direction of the vector product $\vec{A} \times \vec{B}$.

1.89 Given two vectors $\vec{A} = -2\hat{\imath} + 3\hat{\jmath} + 4\hat{k}$ and $\vec{B} = 3\hat{\imath} + 1\hat{\jmath} - 3\hat{k}$, do the following. (a) Find the magnitude of each vector. (b) Write an expression for the vector difference $\vec{A} - \vec{B}$, using unit vectors. (c) Find the magnitude of the vector difference $\vec{A} - \vec{B}$. Is this the same as the magnitude of $\vec{B} - \vec{A}$? Explain.

1.93 A cube is placed so that one comer is at the origin and three edges are along the x-, y-, and z-axes of a coordinate system (Fig. 1.43). Use vectors to compute (a) the angle between the edge along the z-axis (line ab) and the diagonal from the origin to the opposite comer (line ad), and (b) the angle between line ac (the diagonal of a face) and line ad.



1.95 You are given vectors $\vec{A} = 5\hat{\imath} - 6.5\hat{\jmath}$ and $\vec{B} = -3.5\hat{\imath} + 7\hat{\jmath}$. A third vector $\vec{C}$ lies in the xy-plane. Vector $\vec{C}$ is perpendicular to vector $\vec{A}$, and the scalar product of $\vec{C}$ with $\vec{B}$ is 15. From this information, find the components of vector $\overrightarrow{C}$.

1.96 Two vectors A and B have magnitude $A = 3$ and $B = 3$. Their vector product is $\vec{A} \times \vec{B} = -5\hat{k} + 2\hat{\imath}$. What is the angle between $\vec{A}$ and $\vec{B}$?

1.102 The vector $\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$, called the position vector, points from the origin $(0,0,0)$ to an arbitrary point in space with coordinates (x, y, z). Use what you know about vectors to prove the following: All points (x, y, z) that satisfy the equation $Ax + By + Cz = 0$, where A, B, and C are constants, lie in a plane that passes through the origin and that is perpendicular to the vector $A\hat{\imath} + B\hat{\jmath} + C\hat{k}$. Sketch this vector and the plane.

Chapter 2

Problem 9, 18, 20, 44, 51, 74, 75, 93.

2.9 A car is stopped at a traffic light. It then travels along a straight road so that its distance from the light is given by $x(t) = bt^2 - ct^3$, where $b = 2.4\ \mathrm{m/s^2}$ and $c = 0.12\ \mathrm{m/s^3}$.
(a) Calculate the average velocity of the car for the time interval $t = 0$ s and $t = 10$ s. (b) Calculate the instantaneous velocity of the car at $t = 0$ s, $t = 5$ s, and $t = 10$ s. (c) How long after starting from rest is the car again at rest?

2.18 A car's velocity as a function of time is given by $v_x(t) = \alpha + \beta t^2$, where $\alpha = 3\ \mathrm{m/s}$ and $\beta = 0.1\ \mathrm{m/s^3}$.
(a) Calculate the average acceleration for the time interval $t = 0$ s and $t = 5$ s.
(b) Calculate the instantaneous acceleration for $t = 0$ s and $t = 5$ s. (c) Draw accurate $v_x(t)$ and $a_x(t)$ graphs for the car's motion between $t = 0$ s and $t = 5$ s.

2.28 The position of the front bumper of a test car under microprocessor control is given by $x(t) = 2.17\ \mathrm{m} + (4.8\ \mathrm{m/s^2})t^2 - (0.1\ \mathrm{m/s^6})t^6$. (a) Find its position and acceleration at the instants when the car has zero velocity. (b) Draw $x(t)$, $v_x(t)$ and $a_x(t)$ graphs for the motion of the bumper between $t = 0$ s and $t = 2$ s.

2.44 A hot-air balloonist, rising vertically with a constant velocity of magnitude $5\ \mathrm{m/s}$, releases a sandbag at an instant when the balloon is $40\ \mathrm{m}$ above the ground. After it is released, the sandbag is in free fall. (a) Compute the position and velocity of the sandbag at 0.25 s and 1.00 s after its release. (b) How many seconds after its release will the bag strike the ground? (c) With what magnitude of velocity does it strike the ground? (d) What is the greatest height above the ground that the sandbag reaches? (e) Sketch $x(t)$, $v_x(t)$ and $a_x(t)$ graphs for the motion.

***251** The acceleration of a mororcycle is given by $a_x(t) = At - Bt^2$, where $A = 1.5\ \mathrm{m/s^3}$ and
$B = 0.12\ \mathrm{m/s^4}$. The motorcycle is at rest at the origin at time $t = 0$. (a) Find its position and velocity as functions of time. (b) Calculate the maximum velocity it attains.

***2.74** An object's velocity is measured to be $v_x(t) = \alpha - \beta t^2$, where $\alpha = 4\ \mathrm{m/s}$ and $\beta = 2\ \mathrm{m/s^3}$. At $t = 0$ the object is at $x = 0$. (a) Calculate the object's position and acceleration as functions of time. (b) What is the object's maximum positive displacement from the origin?

***2.75**. The acceleration of a particle is given by $a_x(t) = -2\mathrm{m/s^2} + (3\ \mathrm{m/s^3})t$. (a) Find the initial velocity v_{0x}, such that the particle will have the same x-coordinate at $t = 4$ s as it had at $t = 0$. (b) What will be the velocity at $t = 4$ s?

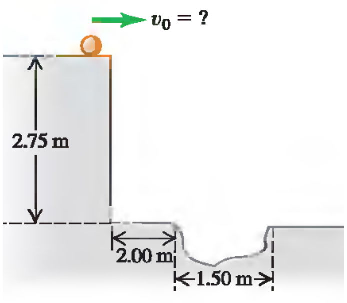
2.93 Two cars, A and B, travel in a straight line. The distance of A from the starting point is given as a function of time by $x_A(t) = \alpha t + \beta t^2$, with $\alpha = 2.6\ \mathrm{m/s}$ and $\beta = 1.2\ \mathrm{m/s^2}$. The distance of B from the starting point is $x_B(t) = \gamma t^2 - \delta t^3$, with $\gamma = 2.8\ \mathrm{m/s^2}$ and $\delta = 0.2\ \mathrm{m/s^3}$.(a) Which car is ahead just after they leave the starting point? (b) At what time(s) are the cars at the same point? (c) At what time(s) is the distance from A to B neither increasing nor decreasing? (d) At what time(s) do A and B have the same acceleration?

Chapter 3

Problem 4, 14, 46, 54, 56, 75, 80, 82, 83, 91

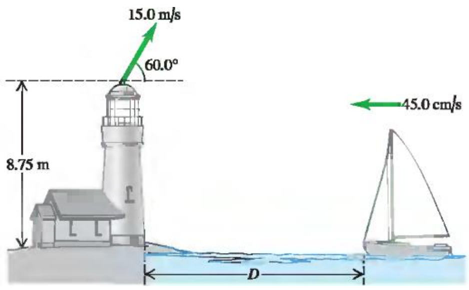
3.4. If $\vec{r} = bt^2\hat{\imath} + ct^3\hat{\jmath}$, where b and c are positive constants, when does the velocity vector make an angle of $45°$ with the x -and y -axes?

3.14. A small marble rolls horizontally with speed v_0 off the top of a platform $2.75\ \mathrm{m}$ tall and feels no appreciable air resistance. On the level ground, $2\ \mathrm{m}$ from the base of the platform, there is a gaping hole in the ground (Fig. 3.40.) For what range of marble speeds v_0 will the marble land in the hole?

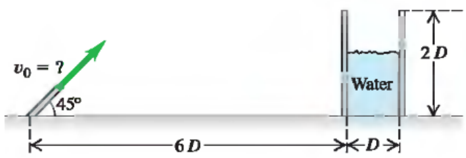


3.46 A bird flies in the xy-plane with a velocity vector given by $v = (\alpha - \beta t^2)\hat{\imath} + \gamma t\hat{\jmath}$, with $\alpha = 2.4\ \mathrm{m/s}$, $\beta = 1.6\ \mathrm{m/s^2}$, and - $\gamma = 4\ \mathrm{m/s^3}$. The positive y-direction is verticly upward At $t = 0$ the bird is at the origin. (a) Calculate the position and acceleration vectors of the bird as functions of time. (b) What is the bird's altitude (y-coordinate) as it flies over $x = 0\ \mathrm{m}$ for the first time after $t = 0$?

3.54 As; a ship is approaching the dock at $45\ \mathrm{cm/s}$, an important piece of landing equipment needs to be thrown to it before it can dock. This equipment is thrown at $15\ \mathrm{m/s}$ at $60°$ above the horizontal from the top of a tower at the edge of the water, $8.75\ \mathrm{m}$ above the ship's deck. For this equipment to land at the front of the ship, at what distance D from the dock should the ship be when the equipment is thrown? Air resistance can be neglected.



3.56 A water hose is used to fill a large cylindrical storage tank of diameter D and height $2D$. The hose shoots the water at $45°$ above the horizontal from the same level as the base of the tank and is a distance $6D$ away. For what range of launch speeds (v_0) will the water enter the tank? Ignore air resistance, and express your answer in terms of D and g.



3.75 A rock tied to a rope moves in the xy -plane. Its coordinates are given as functions of time by
$x(t) = R\cos(\omega t)$, $y(t) = R\sin(\omega t)$
Where R and ω are constants. (a) Show that the rock's distance from the origin is constant and equal to R - that is, that its path is a circle of radius R. (b) Show that at every point the rock's velocity is perpendicular to its position vector. (c) Show that the rock's acceleration is always opposite in direction to its position vector and has magnitude $\omega^2 R$. (d) Show that the magnitude of the rock's velocity is constant and equal to ωR. (e) Combine the results of parts (c) and (d) to show that the rock's acceleration has constant magnitude v^2/R.

3.80. ***Raindrops***. When a train's velocity is 12 m/s eastward, raindrops that are falling vertically with respect to the earth make traces that are inclined $30°$ to the vertical on the windows of the train. (a) What is the horizontal component of a drop's velocity with respect to the earth? With respect to the train? (b) What is the magnitude of the velocity of the raindrop with respect to the earth? With respect to the train?

3.82 An elevator is moving upward at a constant speed of 2.5 m/s. A bolt in the elevator ceiling 3 m above the elevator floor works loose and falls. (a) How long does it take for the bolt to fall to the elevator floor? What is the speed of the bolt just as it hits the elevator floor (b) according to an observer in the elevator? (c) According to an observer standing on one of the floor landings of the building? (d) According to the observer in part (c), what distance did the bolt travel between the ceiling and the floor of the elevator?

3.83 Suppose the elevator in Problem 3.82 starts from rest and maintains a constant upward acceleration of 4 m/s^2, and the bolt falls out the instant the elevator begins to move. (a) How long does it take for the bolt to reach the floor of the elevator? (b) Just as it reaches the floor, how fast is the bolt moving according to an observer (i) in the elevator? (ii) Standing on the floor landings of the building? (c) According to each observer in part (b), how far has the bolt traveled between the ceiling and floor of the elevator?

3**.91** For no apparent reason, a poodle is running at a constant speed of $v = 5 \text{ m/s}$ in a circle with radius $R = 2.5 \text{ m}$. Let $\vec{v}_1$ be the velocity vector at time t_1 and let $\vec{v}_2$ be the velocity vector at time t_2 . Consider $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$ and $\Delta t = t_2 - t_1$. Recall that $\vec{a}_{ave} = \Delta\vec{v}/\Delta t$. For $\Delta t = 0.5$ s, 0.1 s, and 0.05 s calculate the magnitude (to four significant figures) and direction (relative to $\vec{v}_1$) of the average acceleration $\vec{a}_{ave}$. Compare your results to the general expression for the instantaneous acceleration a for uniform circular motion that is derived in the text.

Chapter 4

Problem 15, 59, 60, 62

4.15. A small $8\ \mathrm{kg}$ rocket burns fuel that exerts a time-varying upward force on the rocket. This force obeys the equation $F = A + Bt^2$. Measurements show that at $t = 0\ \mathrm{s}$, the force is $100\ \mathrm{N}$, and at the end of the first $2\ \mathrm{s}$, it is $150\ \mathrm{N}$,. (a) Find the constants A, and B, including their SI units. (b) Find the net force on this rocket and its acceleration (i) the instant after the fuel ignites and (ii) $3\ \mathrm{s}$ after fuel ignition. (c) Suppose you were using this rocket in outer space, far from all gravity. What would its acceleration be $3\ \mathrm{s}$ after fuel ignition?

4.59 An object with mass m moves along the x -axis. Its position as a function of time is given by $x(t) = At - Bt^3$, where A and B are constants. Calculate the net force on the object as a function of time.

4.60 An object with mass m initially at rest is acted on by a force $\vec{F} = k_1\hat{\imath} + k_2t^3\hat{\jmath}$, where k_1 and k_2 are constants. Calculate the velocity $\vec{v}(t)$ of the object as a function of time.

4.62 An object of mass m is at rest in equilibrium at the origin. At $t = 0\ \mathrm{s}$, a new force $\vec{F}(t)$ is applied that has components

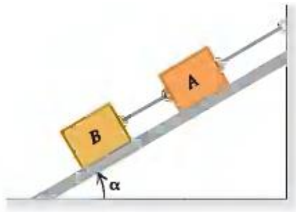
$$F_x(t) = k_1 + k_2y$$

$$F_y(t) = k_3t$$

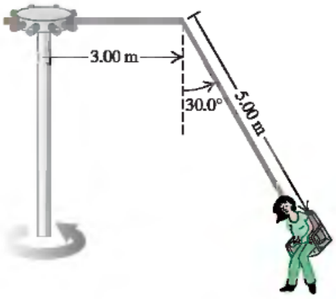
where k_1, k_2 and k_3 are constants. Calculate the position $\vec{r}(t)$ and velocity $\vec{v}(t)$ vectors as functions of time.

Chapter 5

Problem 14, 52, 54, 65, 67, 83, 87, 88, 91, 93, 102, 114, 118, 119.

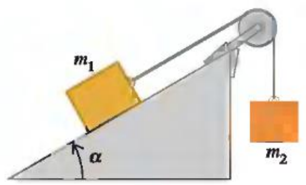


5.14 Two blocks, each with weight w, are held in place on a frictionless incline (Fig. 5.48). In terms of wand the angle α of the incline, calculate the tension in (a) the rope connecting the blocks and (b) the rope that connects block A to the wall. (c) Calculate the magnitude of the force that the incline exerts on each block. (d) Interpret your answers for the cases $\alpha = 0°$ and $\alpha = 0°$.



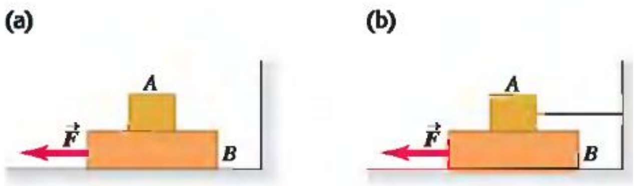
5.52 The "Giant Swing" at a county fair consists of a vertical central shaft with a number of horizontal arms attached at its upper end (Fig. 5.57). Each arm supports a seat suspended from a cable $5\ \mathrm{m}$ long, the upper end of the cable being fastened to the arm at a point $3\ \mathrm{m}$ from the central shaft. (a) Find the time of one revolution of the swing if the cable supporting a seat makes an angle of $30°$ with the vertical. (b) Does the angle depend on the weight of the passenger for a given rate of revolution?

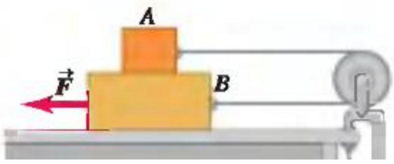
5.54. A small button placed on a horizontal rotating platform with diameter $0.32\ \mathrm{m}$ will revolve with the platform when it is brought up to a speed of $40\ \mathrm{rev/min}$, provided the button is no more than $0.15\ \mathrm{m}$ from the axis. (a) What is the coefficient of static friction between the button and the platform? (b) How far from the axis can the button be placed, without slipping. if the platform rotates at $40\ \mathrm{rev/min}$?



5.65. A block with mass m_1, is placed on an inclined plane with slope angle α and is connected to a second hanging block with mass m_2 by a cord passing over a small, frictionless pulley (Fig. 5.62). The coefficient of static friction is μ_s and the coefficient of kinetic friction is μ_k (a) Find the mass m_2 for which block m_1 moves up the plane at constant speed once it is set in motion. (b) Find the mass m_2 for which block m_1 moves down the plane at constant speed once it is set in motion. (c) For what range of values of m_2 will the blocks remain at rest if they are released from rest?

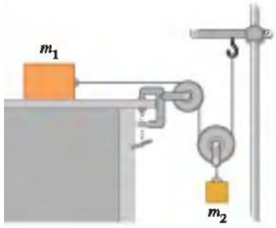
5.67. Block A in Fig. 5.64 weighs $1.2\ \mathrm{N}$ and block B weighs $3.6\ \mathrm{N}$. The coefficient of kinetic friction between all surfaces is 0.3. Find the magnitude of the horizontal force $\vec{F}$ necessary to drag block B to the left at constant speed (a) if A rests on B and moves with it (Fig. 5.64a) and (b) if A is held at rest (Fig. 5.64b).



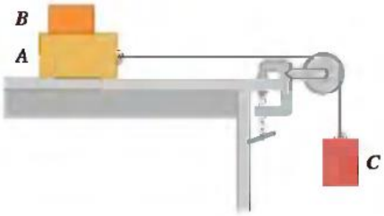


5.83. Block A in Fig. 5.68 weighs $1.4\ \mathrm{N}$, and block B weighs $4.2\ \mathrm{N}$. The coefficient of kinetic friction between all surfaces is 0.3. Find the magnitude of the horizontal force $\vec{F}$ necessary to drag block B to the left at constant speed if A and B are connected by a light, flexible cord passing around a fixed, frictionless pulley.

5.87. In terms of m_1 m_2, and g, find the accelerations of each block in Fig. 5.71. There is no friction anywhere in the system.

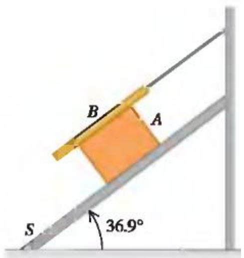


5.88. Block B, with mass $5\ \mathrm{kg}$, rests on block A, with mass $8\ \mathrm{kg}$, which in turn is on a horizontal tabletop (Fig. 5.72). There is no friction between block A and the tabletop, but the coefficient of static friction between block A and block B is 0.75. A light string attached to block A passes o ver a frictionless, massless pulley, and block C is suspended from the other end of the string. What is the largest mass that block C can have so that blocks A and B still slide together when the system is released from rest?



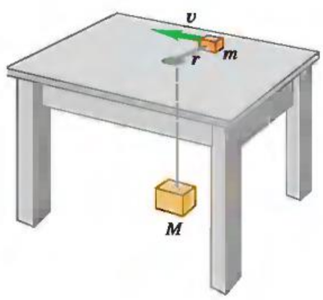
5.91. A block is placed against the vertical front of a cart as shown in Fig. 5.73. What acceleration must the cart have so that block A does not fall? The coefficient of static friction between the block and the cart is μ_s. How would an observer on the cart describe the behavior of the block?

5.93. Block A, with weight $3w$, slides down an inclined plane S of slope angle 36.9° at a constant speed while plank B, with weight w, rests on top of A. The plank is attached by a cord to the wall (Fig. 5.75). (a) Draw a diagram of all the forces acting on block A. (b) If the coefficient of kinetic friction is the same between A and B and between S and A, determine its value.

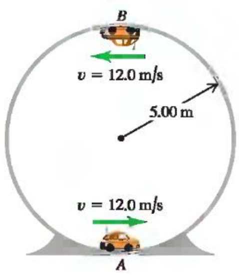


5.102. A rock with mass m slides with initial velocity v_0 on a horizontal surface. A retarding force F_R that the surface exerts on the rock is proportional to the square root of the instantaneous velocity of the rock ($F_R = -kv^{0.5}$). (a) Find expressions for the velocity and position of the rock as a function of time. (b) In terms of m, k, and v_0, at what time will the rock come to rest? (c) In terms of m, k, and v_0, what is the distance of the rock from its starting point when it comes to rest?

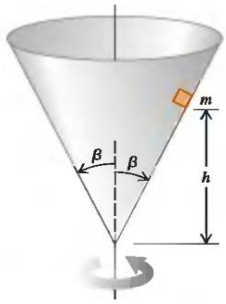
5.114. A small block with mass m rests on a frictionless horizontal tabletop a distance r from a hole in the center of the table (Fig. 5.79). A string tied to the small block passes down through the hole, and a larger block with mass M is suspended from the free end of the string. The small block is set into uniform circular motion with radius r and speed v. What must v be if the large block is to remain motionless when released?



5.118. A small remote-control car with mass $1.6\ \mathrm{kg}$ moves at a constant speed of $v = 12\ \mathrm{m/s}$ in a vertical circle inside a hollow metal cylinder that has a radius of $5\ \mathrm{m}$ (Fig 5.82). What is the magnitude of the normal force exerted on the car by the walls of the cylinder at (a) point A (at the bottom of the vertical circle) and (b) point B (at the top of the vertical circle)?



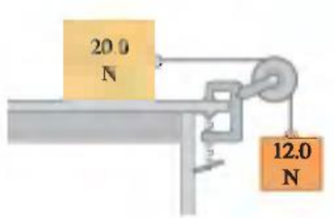
5.119. A small block with mass m is placed inside an inverted cone that is rotating about a vertical axis such that the time for one revolution of the cone is T (Fig. 5.83). The walls of the cone make an angle β with the vertical. The coefficient of static friction between the block and the cone is μ_s. If the block is to remain at a constant height h above the apex of the cone, what are the maximum and minimum values of T?



Chapter 6

Problem 7, 32, 43, 62, 69, 74, 80, 92, 96.

6.7. Two blocks are connected by a very light string passing over a massless and frictionless pulley (Figure 6.30). Traveling at constant speed, the $20\ \mathrm{N}$ block moves $75\ \mathrm{cm}$ to the right and the $12\ \mathrm{N}$ block moves $75\ \mathrm{cm}$ downward. During this process, how much work is done (a) on the $12\ \mathrm{N}$ block by (i) gravity and (ii) the tension in the string? (b) On the $20\ \mathrm{N}$ block by (i) gravity, (ii) the tension in the string, (ill) friction, and (iv) the normal force? (c) Find the total work done on each block.

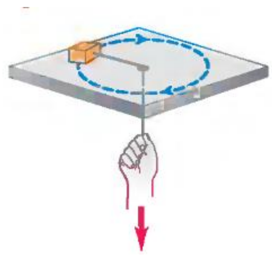


6.32. A balky cow is leaving the barn as you try harder and harder to push her back in. In coordinates with the origin at the barn door, the cow walks from $x = 0$ to $x = 6.9\ \mathrm{m}$ as you apply a force with x - component $F = -(20\ \mathrm{N} + (3\ \mathrm{N/m})x)$. How much work does the force you apply do on the cow during this displacement?

6.43. How many joules of energy does a 100 -watt light bulb use per hour? How fast would a $70\ \mathrm{kg}$ person have to run to have that amount of kinetic energy?

6.62. A $5\ \mathrm{kg}$ package slides $1.5\ \mathrm{m}$ down a long ramp that is inclined at 12 below the horizontal. The coefficient of kinetic friction between the package and the ramp is $\mu_k = 0.31$. Calculate (a) the work done on the package by friction; (b) the work done on the package by gravity; (c) the work done on the package by the normal force; (d) the total work done on the package. (e) If the package has a speed of $2.2\ \mathrm{m/s}$ at the top of the ramp, what is its speed after sliding $1.5\ \mathrm{m}$ down the ramp?

6.68. A small block with a mass of $0.12\ \mathrm{kg}$ is attached to a cord passing through a hole in a frictionless, horizontal surface (Fig. 6.34). The block is originally revolving at a distance of $0.4\ \mathrm{m}$ from the hole with a speed of $0.7\ \mathrm{m/s}$. The cord is then pulled from below, shortening the radius of the circle in which the block revolves to $0.1\ \mathrm{m}$. At this new distance, the speed of the block is observed to be $2.8\ \mathrm{m/s}$. (a) What is the tension in the cord in the original situation when the block has speed $v = 0.7\ \mathrm{m/s}$? (b) What is the tension in the cord in the final situation when the block has speed $= 2.8\ \mathrm{m/s}$? (c) How much work was done by the person who pulled on the cord?



6.74. A force in the $+x$ -direction has magnitude $F = b/x^n$, where b and n are constants. (a) For $n > 1$, calculate the work done on a particle by this force when the particle moves along the x -axis from $x = x_0$ to infinity. (b) Show that for $0 < n < 1$, even though F becomes zero as x becomes very large, an infinite amount of work is done by F when the particle moves from $x = x_0$ to infinity.

6.80 A physics professor is pushed up a ramp inclined upward at $30°$ above the horizontal as he sits in his desk chair that slides on frictionless rollers. The combined mass of the professor and chair is $85\ \mathrm{kg}$. He is pushed $2.5\ \mathrm{m}$ along the incline by a group of students who together exert a constant horizontal force of $600\ \mathrm{N}$. The professor's speed at the bottom of the ramp is $2\ \mathrm{m/s}$. Use the work-energy theorem to find his speed at the top of the ramp.

6.92. The engine of a car with mass m supplies a constant power P to the wheels to accelerate the car. You can ignore rolling friction and air resistance. The car is initially at rest.

(a) Show that the speed of the car is given as a function of time by $v = \left(\frac{2Pt}{m}\right)^{1/2}$

(b) Show that the acceleration of the car is given as a function of time by $a = \left(\frac{P}{2mt}\right)^{1/2}$

(c) Show that the displacement as a function of time is given by $x - x_0 = \left(\frac{8P}{9m}\right)^{1/2} t^{3/2}$

6.96. An object has several forces acting on it. One of these forces is $\vec{F}_1 = axy\hat{\imath}$, a force in the x -direction whose magnitude depends on the position of the object, with $a = 2.5\ \mathrm{N/m^2}$. Calculate the work done on the object by this force for the following displacements of the object: (a) The object starts at the point $x = 0$, $y = 3\ \mathrm{m}$ and moves parallel to the x-axis to the point $x = 2\ \mathrm{m}$, $y = 3\ \mathrm{m}$. (b) The object starts at the point $x = 2\ \mathrm{m}$, $y = 0$ and moves in the y -direction to the point $x = 2\ \mathrm{m}$, $y = 3\ \mathrm{m}$. (c) The object starts at the origin and moves on the line $y = 1.5\ x$ to the point $x = 2\ \mathrm{m}$, $y = 3\ \mathrm{m}$.

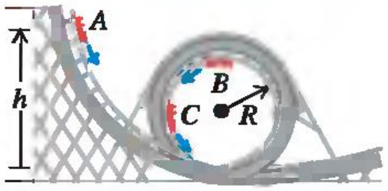
Chapter 7

Problem 33, 46, 55, 63, 65, 67, 74, 82, 86.

7.33. A force parallel to the x-axis acts on a particle moving along the x-axis. This force produces potential energy U(x) given by $U(x) = ax^4$, where $a = 1.2\ J/m^4$. What is the force (magnitude and direction) when the particle is at x = -0.8 m?

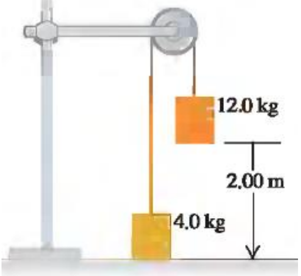
7.46. Riding a Loop-the-Loop. A car in an amusement park ride rolls without friction around the track shown in Fig. 7.32. It starts from rest at point A at a height h above the bottom of the loop. Treat the car as a particle. (a) What is the minimum value of h (in terms of R) such that the car moves around the loop without falling off at the top (point B)? (b) If h = 3.5R and R = 20 m. compute the speed, radial acceleration, and tangential acceleration of the passengers when the car is at point C, which is at the end of a horizontal diameter. Show these acceleration components in a diagram, approximately to scale.

Figure 7.32 Problem 7.46.

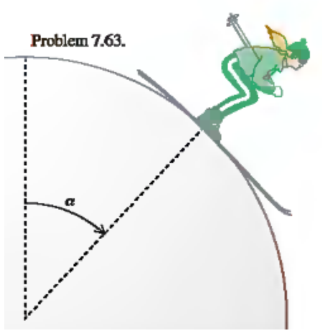


7.55. A system of two paint buckets connected by a lightweight rope is released from rest with the 12 kg bucket 2 m above the floor (Fig. 7.36). Use the principle of conservation of energy to find the speed with which this bucket strikes the floor. You can ignore friction and the mass of the pulley.

Problem 7.55.



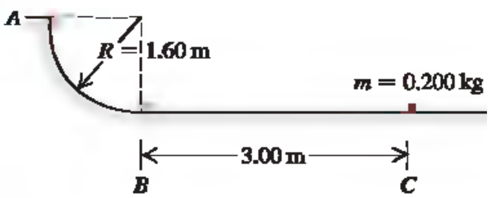
7.63. A skier starts at the top of a very large, frictionless snowball, with a very small initial speed, and skis straight down the side (Fig. 7.38). At what point does she lose contact with the snowball and fly off at a tangent? That is, at the instant she loses contact with the snowball, what angle α does a radial line from the center of the snowball to the skier make with the vertical?



Problem 7.63.

7.65. In a truck-loading station at a post office, a small 0.2 kg package is released from rest at point A on a track that is one-quarter of a circle with radius 1.6 m (Fig. 7.39). The size of the package is much less than 1.6 m, so the package can be treated as a particle. It slides down the track and reaches point B with a speed of 4.8 m/s. From point B. it slides on a level surface a distance of 3 m to point C. where it comes to rest (a) What is the coefficient of kinetic friction on the

Problem 7.65.

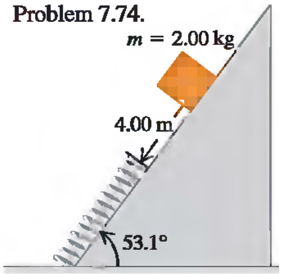


horizontal surface? (b) How much work is done on the package by friction as it slides down the circular arc from A to B?

7.67. A certain spring is found not to obey Hooke's law; it exerts a restoring force $F_x(x) = -ax - bx^2$ if it is stretched or compressed, where a = 60 N/m and b = 18 N/m^2. The mass of the spring is negligible. (a) Calculate the potential-energy function U(x) for this spring. Let U = 0 when x = 0. (b) An object with mass 0.9 kg on a frictionless, horizontal surface is attached to this spring, pulled a distance 1 m to the right (the +x-direction) to stretch the spring, and released. What is the speed of the object when it is 0.5 m to the right of the x = 0 equilibrium position?

7.74. A 2kg package is released on a 53.1° incline, 4 m from a long spring with force constant 120 N/m that is attached at the bottom of the incline (Fig. 7.43). The coefficients of friction between the package and the incline are μ_s= 0.4 and μ_k = 0.20. The mass of the spring is negligible. (a) What is the speed of the package just before it reaches the spring? (b) What is the maximum compression of the spring? (c) The package rebounds back up the incline. How close does it get to its initial position?

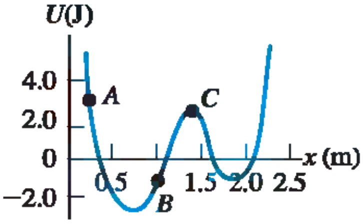
Problem 7.74.



7.82. (a) Is the force F = Cy^{2}j, where C is a negative constant with units of N/m^2, conservative or non-conservative? Justify your answer. (b) Is the force F = Cy^{2}i, where C is a negative constant with units of N/ m^2, conservative or non-conservative? Justify your answer.

7.86. A particle moves along the x-axis while acted on by a single conservative force parallel to the x-axis. The force corresponds to the potential-energy function graphed in Fig. 7.45. The particle is released from rest at point A. (a) What is the direction of the force on the particle when it is at point A? (b) At point B? (c) At what value of x is the kinetic energy of the particle a maximum? (d) What is the force on the particle when it is at point C? (e) What is the largest value of x reached by the particle during its motion? (f) What value or values of x correspond to points of stable equilibrium? (g) Of unstable equilibrium?

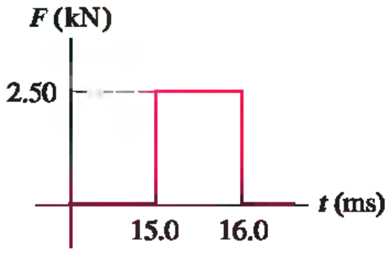
Problem 7.86.



Chapter 8

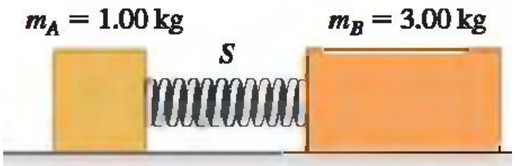
Problem 13, 20, 28, 54, 61, 65, 69, 71, 87, 102.

Figure 8.34 Exercise 8.13.



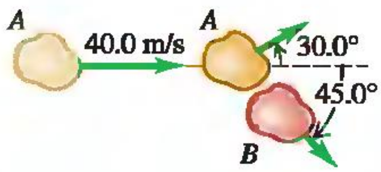
8.13. A 2kg stone is sliding to the right on a frictionless horizontal surface at 5 m/s when it is suddenly struck by an object that exerts a large horizontal force on it for a short period of time. The graph in Fig. 8.34 shows the magnitude of this force as a function of time. (a)What impulse does this force exert on the stone? (b) Just after the force stops acting, find the magnitude and direction of the stone's velocity if the force acts (i) to the right or (ii) to the left.

Figure 8.35 Exercise 8.20.



8.20. Block A in Fig. 8.35 has mass 1 kg, and block B has mass 3 kg. The blocks are forced together, compressing a spring S between them; then the system is released from rest on a level, frictionless surface. The spring, which has negligible mass, is not fastened to either block and drops to the surface after it has expanded. Block B acquires a speed of 1.2 m/s. (a) What is the final speed of block A? (b) How much potential energy was stored in the compressed spring?

Figure 8.36 Exercise 8.28.



8.28. Asteroid Collision Two asteroids of equal mass in the asteroid belt between Mars and Jupiter collide with a glancing blow. Asteroid A, which was initially traveling at 40 m/s, is deflected 30 degree from its original direction, while asteroid B travels at 45 degree to the original direction of A (Fig. 8.36). (a) Find the speed of each asteroid after the collision. (b) What fraction of the original kinetic energy of asteroid A dissipates during this collision?

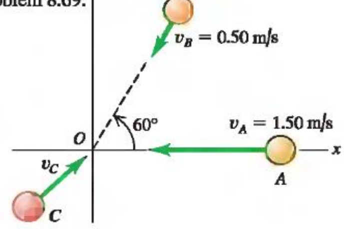
8.54. A system consists of two particles. At t = 0 one particle is at the origin; the other, which has a mass of 0.5 kg, is on the y-axis at y = 6 m. At t = 0 the center of mass of the system is on the y-axis at y = 2.4 m. The velocity of the center of mass is given by $0.75\frac{m}{s^3}t^2\,\hat{\imath}$. (a) Find the total mass of the system. (b) Find the acceleration of the center of mass at any time t. (c) Find the net external force acting on the system at t = 3 s.

***8.61**. A single-stage rocket is fired from rest from a deep-space platform, where gravity is negligible. If the rocket burns its fuel in 50 s and the relative speed of the exhaust gas is v_{ex} = 2100 m/s, what must the mass ratio m_0/m be for a final speed v of 8 km/s (about equal to the orbital speed of an earth satellite)?

8.65. Just before it is struck by a racket, a tennis ball weighing 0.56 N has a velocity of $(20\frac{m}{s}\,\hat{\imath} - 4\frac{m}{s}\,\hat{\jmath})$. During the 3 ms that the racket and ball are in contact, the net force on the ball is constant and equal to $(-380N\,\hat{\imath} - 110N\,\hat{\jmath})$ (a) What are the x- and y-components of the impulse of the net force applied to the ball? (b) What are the x- and y-components of the final velocity of the ball?

8.69. Spheres A (mass 0.02 kg), B (mass 0.03 kg), and C (mass 0.05 kg) are approaching the origin as they slide on a frictionless air table (Fig. 8.41). The initial velocities of A and B are given in the figure. All three spheres arrive at the origin at the same time and stick together. (a) What must the x- and y-components of the initial velocity of C be if all three objects are to end up moving at 0.5 m/s in the +x-direction after the collision? (b) If C has the velocity found in part (a), what is the change in the kinetic energy of the system of three spheres as a result of the collision?

Figure 8.41
Problem 8.69.



8.71. Changing Mass. A railroad hopper car filled with sand is rolling with an initial speed of 15 m/s on straight, horizontal tracks. You can ignore frictional forces on the railroad car. The total mass of the car plus sand is 85,000 kg. The hopper door is not fully closed so sand leaks out the bottom. After 20 min, 13,000 kg of sand has leaked out. Then what is the speed of the railroad car? (Compare your analysis with that used to solve Exercise 8.27.)

8.87. In a shipping company distribution center, an open cart of mass 50 kg is rolling to the left at a speed of 5 m/s (Fig. 8.46). You can ignore friction between the cart and the floor. A 15 kg package slides down a chute that is inclined at 37° from the horizontal and leaves the end of the chute with a speed of 3 m/s. The package lands in the cart and they roll off together. If the lower end of the chute is a vertical distance of 4 m above the bottom of the cart, what are (a) the speed of the package just before it lands in the cart and (b) the final speed of the cart?

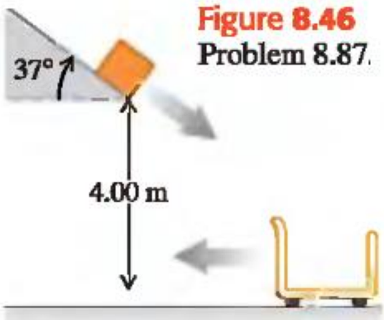


Figure 8.46
Problem 8.87.

8.102. A 20 kg projectile is fired at an angle of 60° above the horizontal with a speed of 80 m/s. At the highest point of its trajectory, !he projectile explodes into two fragments with equal mass, one of which falls vertically with zero initial speed. You can ignore air resistance. (a) How far from the point of firing does the other fragment strike if the terrain is level? (b) How much energy is released during the explosion?

Chapter 9

Ch9: 6, 7, 26, 30, 67, 80, 85.

9.6. At t=0 the current to a DC electric motor is reversed, resulting in an angular displacement of the motor shaft given by

$$\theta(t) = 250\text{rad/s}\, t - 20\text{rad/s}^2\, t^2 - 1.5\text{ rad/s}^3\, t^3$$

(a) At what time is the angular velocity of the motor shaft zero?
(b) Calculate the angular acceleration at the instant that the motor shaft has zero angular velocity.
(c) How many revolutions does the motor shaft turn through between the time when the current is reversed and the instant when the angular velocity is zero?
(d) How fast was the motor shaft rotating at t = 0, when the current was reversed?
(e) Calculate the average angular velocity for the time period from t = 0 to the time calculated in part (a).

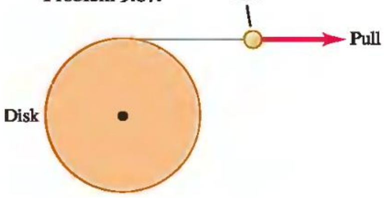
9.7. The angle θ through which a disk drive turns is given by $\theta(t) = a\,t + b\,t^2 - c\,t^3$ where a, b, and c are constants, t is in seconds, and θ is in radians. When t = 0, $\theta = \pi/4$ rad and the angular velocity is 2 rad/s, and when t = 1.50 s, the angular acceleration is 1.25 rad/s^2.
(a) Find a, b, and c, including their units.
(b) What is the angular acceleration when $\theta = \pi/4$ rad?
(c) What are θ and the angular velocity when the angular acceleration is 3.50 rad/s^2?

9.26. An electric turntable 0.750 m in diameter is rotating about a fixed axis with an initial angular velocity of 0.250 rev/s and a constant angular acceleration of 0.900 rev/s^2. (a) Compute the angular velocity of the turntable after 0.200 s. (b) Through how many revolutions has the turntable spun in this time interval? (c) What is the tangential speed of a point on the rim of the turntable at t = 0.200 s? (d) What is the magnitude of the resultant acceleration of a point on the rim at t = 0.200 s?

9.30. At t = 3.00 s a point on the rim of a 0.200-m-radius wheel has a tangential speed of 50.0 m/s as the wheel slows down with a tangential acceleration of constant magnitude 10.0 m/S^2.
(a) Calculate the wheel's constant angular acceleration.
(b) Calculate the angular velocities at t = 3.00 s and t = O.
(c) Through what angle did the wheel turn between t = 0 and t = 3.00 s? (d) At what time will the radial acceleration equal g?

*__9.67__. A disk of radius 25.0 cm is free to turn about an axle perpendicular to it through its center It has very thin but strong string wrapped around its rim, and the string is attached to a ball that is pulled tangentially away from the rim of the disk (Fig. 9.33). The pull increases in magnitude and produces an acceleration of the ball that obeys the equation a(t)=At, where t is in seconds and A is a constant. The cylinder starts from rest, and at the end of the third second, the ball's acceleration is 1.80 mls^2. (a) Find A. (b) Express the angular acceleration of the disk as a function of time. (c) How much time after the disk has begun to turn does it reach an angular speed of 15.0 rad/s? (d) Through what angle has the disk turned just as it reaches 15.0 rad/s? (Hint: See Section 2.6.)

Problem 9.67.



9.80. A uniform, solid disk with mass m and radius R is pivoted about a horizontal axis through its center. A small object of the same mass m is glued to the rim of the disk. If the disk is released from rest with the small object at the end of a horizontal radius, find the angular speed when the small object is directly below the axis.

9.85. The pulley in Fig. 9.35 has radius R and a moment of inertia I. The rope does not slip over the pulley, and the pulley spins on a frictionless axle. The coefficient of kinetic friction between block A and the tabletop is μ_k. The system is released from rest, and block B descends. Block A has mass m_A and block B has mass m_B . Use energy methods to calculate the speed of block B as a function of the distance d that it has descended.

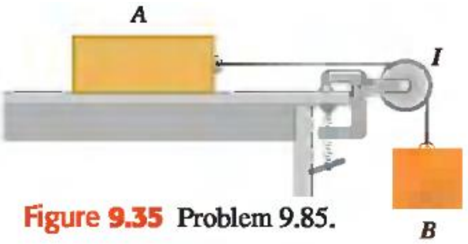


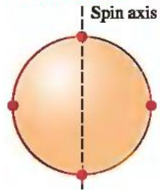
Figure 9.35 Problem 9.85.

Chapter 10

Ch10: 8, 29, 35, 38, 40, 64, 70, 71, 83, 87, 91, 100.

10.8. A uniform, 8.40-kg, spherical shell 50.0 cm in diameter has four small 2.00-kg masses attached to its outer surface and equally spaced around it. This combination is spinning about an axis running through the center of the sphere and two of the small masses. What friction torque is needed to reduce its angular speed from 75.0 rpm to 50.0 rpm in 30.0 s?

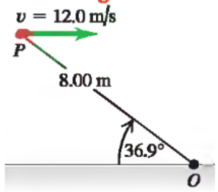
Figure 10.42



10.28. The engine delivers 175 hp to an aircraft propeller at 2400 rev/min. (a) How much torque does the aircraft engine provide? (b) How much work does the engine do in one revolution of the propeller?

10.35. A 2.00-kg rock has a horizontal velocity of magnitude 12.0 m/s when it is at point P in Fig. 10.47.(a) At this instant, what are the magnitude and direction of its angular momentum relative to point O? (b) If the only force acting on the rock 36.9' is its weight, what is the rate of 0 change (magnitude and direction) of its angular momentum at this instant?

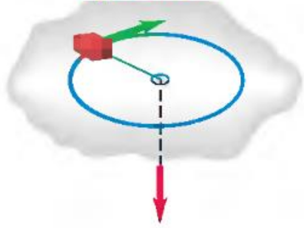
Figure 10.47



10.38. A hollow, thin-walled sphere of mass 12.0 kg and diameter 48.0 cm is rotating about an axle through its center. The angle (in radians) through which it turns as a function of time (in seconds) is given by $\theta(t) = At^2 + Bt^4$, where A has numerical value 1.50 and B has numerical value 1.10. (a) What are the units of the constants A and B? (b) At the time 3.00 s, find (i) the angular momentum of the sphere and (ii) the net torque on the sphere.

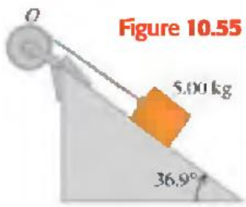
10.40. A small block on a frictionless, horizontal surface has mass of 0.0250 kg. It is attached to a massless cord passing through a hole in the surface (Fig. 10.48). The block is originally revolving at a distance of 0.300 m from the hole with an angular speed of 1.75 rad/s. The cord is then pulled from below, shortening the radius of the circle in which the block revolves to 0.150 m. Model the block as a particle. (a) Is angular momentum of the block conserved? Why or why not? (b) What is the new angular speed? (c) Find the change in kinetic energy of the block. (d) How much work was done in pulling the cord?

Figure 10.48



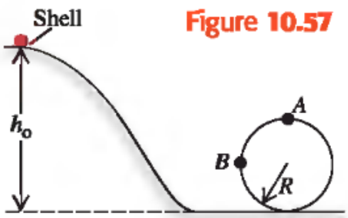
10.64. A block with mass m = 5.00 kg slides down a surface inclined 36.9^0 to the horizontal. The coefficient of kinetic friction is 0.25. A string attached to the block is wrapped around a flywheel on a fixed axis at O. The flywheel has mass 25.0 kg and moment of inertia 0.500 kg m^2 with respect to the axis of rotation. The string pulls without slipping at a perpendicular distance of 0.200 m from that axis. (a) What is the acceleration of the block down the plane? (b) What is the tension in the string?

Figure 10.55



10.70. A thin-walled, hollow spherical shell of mass m and radius r starts from rest and rolls without slipping down the track shown in Fig. 10.57. Points A and B are on a circular part of the track having radius R. The diameter of the shell is very small compared to h_0 and R, and rolling friction is negligible. (a) What is the minimum height h_0 for which this shell will make a complete loop-the-loop on the circular part of the track? (b) How hard does the track push on the shell at point B, which is at the same level as the center of the circle? (c) Suppose that the track had no friction and the shell was released from the same height h_0 you found in part (a). Would it make a complete loop-the-

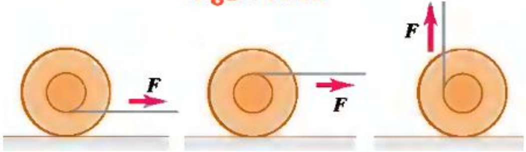
Figure 10.57



loop? How do you know? (d) In part (c), how hard does the track push on the shell at point A, the top of the circle? How hard did it push on the shell in part (a)?

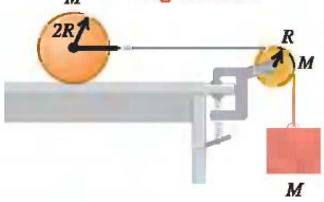
10.71. Figure 10.58 shows three identical yo-yos initially at rest on a horizontal surface. For each yo-yo. the string is pulled in the direction shown. In each case, there is sufficient friction for the yo-yo to roll without slipping. Draw the free-body diagram for each yo-yo. In what direction will each yo-yo rotate? (Try it!) Explain your answers.

Figure 10.58



10.83. A uniform, solid cylinder with mass M and radius 2R rests on a horizontal tabletop. A string is attached by a yoke to a frictionless axle through the center of the cylinder so that the cylinder can rotate about the axle. The string runs over a disk-shaped pulley with mass M and radius R that is mounted on a frictionless axle through its center. A block of mass M is suspended from the free end of the string (Fig. 10.62). The string doesn't slip over the pulley surface, and the cylinder rolls without slipping on the tabletop. Find the magnitude of the acceleration of the block after the system is released from rest.

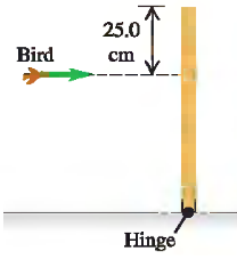
Figure 10.62



10.87. A uniform rod of length L rests on a frictionless horizontal surface. The rod pivots about a fixed frictionless axis at one end. The rod is initially at rest. A bullet traveling parallel to the horizontal surface and perpendicular to the rod with speed v strikes the rod at its center and becomes embedded in it. The mass of the bullet is one-fourth the mass of the rod. (a) What is the final angular speed of the rod? (b) What is the ratio of the kinetic energy of the system after the collision to the kinetic energy of the bullet before the collision?

10.91. A 500.0-g bird is flying horizontally at 2.25 m/s, not paying much attention, when it suddenly flies into a stationary vertical bar, hitting it 25.0 cm below the top (Fig. 10.63). The bar is uniform, 0.750 m long, has a mass of 1.50 kg, and is hinged at its base. The collision stuns the bird so that it just drops to the ground afterward (but soon recovers to fly happily away). What is the angular velocity of the bar (a) just after it is hit by the bird, and (b) just as it reaches the ground?

Figure 10.63



10.100. A uniform ball of radius R rolls without slipping between two rails such that the horizontal distance is d between the two contact points of the rails to the ball.

(a) In a sketch, show that at any instant, $v_{cm} = \omega\sqrt{R^2 - d^2/4}$. Discuss this expression in the limits d = 0 and d = 2R.

(b) For a uniform ball starting from rest and descending a vertical distance h while rolling without slipping down a ramp, $v_{cm} = \sqrt{10gh/7}$. Replacing the ramp with the two rails, show that;

$$v_{cm} = \sqrt{\frac{10gh}{5 + 2/(1 - \frac{d^2}{4R^2})}}$$

In each case, the work done by friction has been ignored.

(c) Which speed in part (b) is smaller? Why? Answer in terms of how the loss of potential energy is shared between the gain in translational and rotational kinetic energies. (d) For which value of the ratio d/ R do the two expressions for the speed in part (b) differ by 5.0%? By 0.50%?

Chapter 12

Problem 11, 27, 37, 39, 40, 41, 49, 73, 74, 77, 82, 83.

12.11. A particle of mass 3m is located 1.00 m from a particle of mass m. (a) Where should you put a third mass M so that the net gravitational force on M due to the two masses is exactly zero? (b) Is the equilibrium of M at this point stable or unstable (i) for points along the line connecting m and 3m, and (Ii) for points along the line passing through M and perpendicular to the line connecting m and 3m?

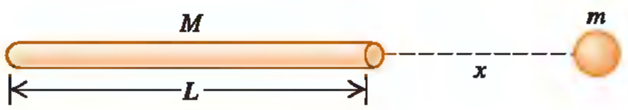
12.27. For a satellite to be in a circular orbit 780 km above the surface of the earth, (a) what orbital speed must it be given, and (b) what is the period of the orbit (in hours)?

12.37. The Helios B spacecraft had a speed of 71 km/s when it was 4.3 X 10^7 km from the sun. (a) Prove that it was not in a circular orbit about the sun. (b) Prove that its orbit about the sun was closed and therefore elliptical.

12.39. A uniform, solid, 1000 kg sphere has a radius of 5m.
(a) Find the gravitational force this sphere exerts on a 2 kg point mass placed at the following distances from the center of the sphere: (i) 5.01 m, and (ii) 2.50 m.
(b) Sketch a qualitative graph of the magnitude of the gravitational force this sphere exerts on a point mass m as a function of the distance r of m from the center of the sphere. Include the region from r = 0 to r → co.

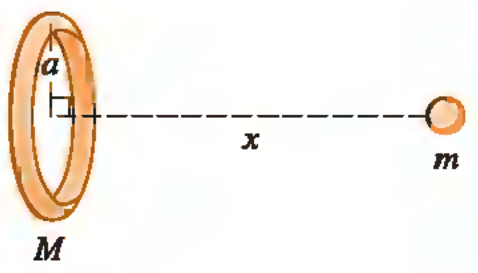
12.40. A thin, uniform rod has length L and mass M. A small uniform sphere of mass m is placed a distance x from one end of the rod, along the axis of the rod (Fig. 12.34). (a) Calculate the gravitational potential energy of the rod-sphere system. Take the potential energy to be zero when the rod and sphere are infinitely far apart. Show that your answer reduces to the expected result when x is much larger than L. (Hint: Use the power series expansion for In(1+x) given in Appendix) (b) Use $F_x = -dU/dx$ to find the magnitude and direction of the gravitational force exerted on the sphere by the rod (see Section 7.4). Show that your answer reduces to the expected result when x is much larger than L.

Figure 12.34 Exercise 12.40 and Problem 12.84.



12.41. Consider the ring-shaped body of Fig. 12.35. A particle with mass m is placed a distance x from the center of the ring, along the line through the center of the ring and perpendicular to its plane. (a) Calculate the gravitational potential energy U of this system. Take the potential energy to be zero when the two objects are far apart. (b) Show that your answer to part (a) reduces to the expected result when x is much larger than the radius a of the ring. (c) Use F. = -dU/dx to find the magnitude and direction of the force on the particle (see Section 7.4).

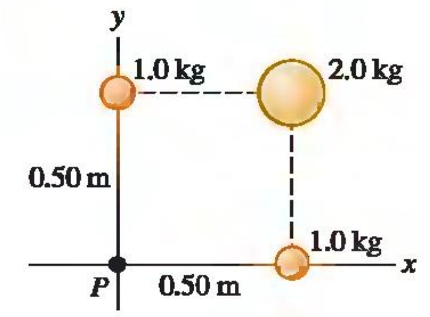
Figure 12.35 Exercise 12.41



(d) Show that your answer to part (c) reduces to the expected result when x is much larger than a.
(e) What are the values of U and F_x. when x = O? Explain why these results make sense.

12.49. Three uniform spheres are fixed at the positions shown in Fig. 12.36. (a) What are the magnitude and direction of the force on a 0.015 kg particle placed at P? (b) If the spheres are in deep outer space and a 0.015 kg particle is released from rest 300m from the origin along a line 45° below the -x-axis, what line 45° below the -x-axis, what will the particle's speed be when it reaches the origin?

Figure 12.36 Problem 12.49.



12.73. Binary Star-Equal Masses. Two identical stars with mass M orbit around their center of mass. Each orbit is circular and has radius R, so that the two stars are always on opposite sides of the circle. (a) Find the gravitational force of one star on the other. (b) Find the orbital speed of each star and the period of the orbit. (c) How much energy would be required to separate the two stars to infinity?

12.74. Binary Star-Different Masses. Two stars, with masses M_1 and M_2 are in circular orbits around their center of mass. The star with mass M_1 has an orbit of radius $_1$; the star with mass M_2 has an orbit of radius R_2. (a) Show that the ratio of the orbital radii of the two stars equals the reciprocal of the ratio of their masses, that is, $R_1/R_2 = M_2/M_1$. (b) Explain why the two stars have the same orbital period, and show that the period T is given by $= 2\pi(R_1 + R_2)^{\frac{3}{2}}/\sqrt{G(M_1 + M_2)}$

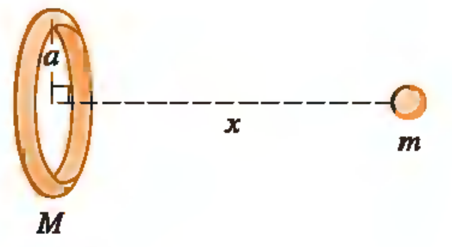
(c) The two stars in a certain binary star system move in circular orbits. The first star, Alpha, has an orbital speed of 36 km/s. The second star, Beta, has an orbital speed of 12 km/s. The orbital period is 137 d. What are the masses of each of the two stars? (d) One of the best candidates for a black hole is found in the binary system called A0620-0090. The two objects in the binary system are an orange star, V616 Monocerotis, and a compact object believed to be a black hole (Fig. 12.22). The orbital period of A0620-0090 is 7.75 hours, the mass of V616 Monocerotis is estimated to be 0.67 times the mass of the sun, and the mass of the black hole is estimated to be 3.8 times the mass of the sun. Assuming that the orbits are circular, find the radius of each object's orbit and the orbital speed of each object. Compare these answers to the orbital radius and orbital speed of the earth in its orbit around the sun.

12.77. Consider a spacecraft in an elliptical orbit around the earth. At the low point, or perigee, of its orbit, it is 400 km above the earth's surface; at the high point, or apogee, it is 4000 km above the earth's surface. (a) What is the period of the spacecraft's orbit? (b) Using conservation of angular momentum, find the ratio of the spacecraft's speed at perigee to its speed at apogee. (c) Using conservation of energy, find the speed at perigee and the speed at apogee. (d) It is necessary to have the spacecraft escape from the earth completely. If the spacecraft's rockets are fired at perigee, by how much would the speed have to be increased to achieve this? What if the rockets were fired at apogee? Which point in the orbit is more efficient to use?

12.62. A uniform wire with mass M and length L is bent into a semicircle. Find the magnitude and direction of the gravitational force this wire exerts on a point with mass m placed at the center of curvature of the semicircle.

*__12.83__. An object in the shape of a thin ring has radius a and mass M. A uniform sphere with mass m and radius R is placed with its center at a distance x to the right of the center of the ring, along a line through the center of the ring, and perpendicular to its plane (Fig. 12.35). What is the gravitational force that the sphere exerts on the ring-shaped object? Show that your result reduces to the expected result when x is much larger than a.

Figure 12.35 Problem 12.83.



Chapter 13

Problem 16, 19, 22, 23, 68, 83, 84, 91, 95, 98

13.16. A 0.4 kg object undergoing SHM has a_x = -2.70 m/s^2 when x = 0.3 m. What is the time for one oscillation?

13.19. A 1.5 kg mass on a spring has displacement as a function of time given by the equation

x(t) = (7.40 cm) cos[(4.16 s^{-1})t - 2.42].

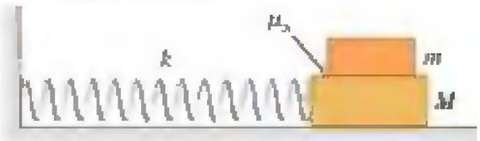
Find (a) the time for one complete vibration; (b) the force constant of the spring; (c) the maximum speed of the mass; (d) the maximum force on the mass; (e) the position, speed, and acceleration of the mass at t = 1 s; (f) the force on the mass at that time.

13.22. A harmonic oscillator has angular frequencyω, and amplitude A. (a) What are the magnitudes of the displacement and velocity when the elastic potential energy is equal to the kinetic energy'? (Assume that U = 0 at equilibrium.) (b) How often does this occur in each cycle? What is the time between occurrences? (c) At an instant when the displacement is equal to A/2, what fraction of the total energy of the system is kinetic and what fraction is potential?

13.23. A 0.5 kg glider, attached to the end of an ideal spring with force constant k = 450 N/m, undergoes SHM with an amplitude of 0.04 m. Compute (a) the maximum speed of the glider; (b) the speed of the glider when it is at x = -0.015 m; (c) the magnitude of the maximum acceleration of the glider; (d) the acceleration of the glider at x = -0.015 m; (e) the total mechanical energy of the glider at any point in its motion.

13.60. A block with mass M rests on a frictionless surface and is connected to a horizontal spring of force constant k. The other end of the spring is attached to a wall (Fig. 13.36). A second block with mass m rests on top of the first block. The coefficient of static friction between the blocks is μ_s. Find the maximum amplitude of oscillation such that the top block will not slip on the bottom block.

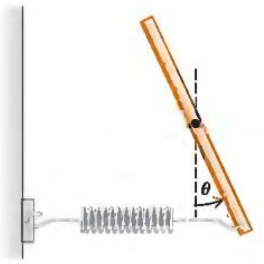
Figure 13.36 Problem 13.68.



13.83. Two point masses m are held in place a distance d apart. Another point mass M is midway between them. M is then displaced a small distance x perpendicular to the line connecting the two fixed masses and released. (a) Show that the magnitude of the net gravitational force on M due to the fixed masses is given approximately by $F_{net} = \frac{16\,GmMx}{d^3}$ If x«d. What is the direction of this force? Is it a restoring force? (b) Show that the mass M will oscillate with an angular frequency of $\frac{4}{d}\sqrt{GM/d}$ and period $\frac{\pi d}{2}\sqrt{d/GM}$. (c) What would the period be if m = 100 kg and d = 25 cm? Does it seem that you could easily measure this period? What things prevent this experiment from easily being performed in an ordinary physics lab? (d) Will M oscillate if it is displaced from the center a small distance x toward either of the fixed masses? Why?

13.84. For a certain oscillator the net force on the body with mass m is given by F_x.=$-cx^3$. (a) What is the potential energy function for this oscillator if we take U = 0 at x = 0? (b) One-quarter of a period is the time for the body to move from x = 0 to x = A. Calculate this time and hence the period. [Hint: Begin with Eq. (13.20), modified to include the potential-energy function you found in part (a), and solve for the velocity v_x. as a function of x. Then replace v_x. with dx/dt. Separate the variable by writing all factors containing x on one side and all factors containing t on the other side so that each side can be integrated. In the x-integral make the change of variable u = x/A. The resulting integral can he evaluated by numerical methods on a computer and has the value $\int_0^1 du/\sqrt{1-u^4} = 1.31$. (c) According to the result you obtained in part (b), does the period depend on the amplitude A of the motion? Are the oscillations simple harmonic?

13.91. A slender, uniform, metal rod with mass M is pivoted without friction about an axis through its midpoint and perpendicular to the rod. A horizontal spring with force constant k is attached to the lower end of the rod, with the other end of the spring attached to a rigid support. If the rod is displaced by a small angle θ from the vertical (Fig. 13.40) and released, show that it moves in angular SHM and calculate the period. (Hint: Assume that the angle e is small enough for the approximations $\sin\theta = \theta$ and $\cos\theta = 1$ to be valid. The motion is simple harmonic if $\frac{d^2\theta}{dt^2} = -\omega^2\theta$ and the period is then $T = 2\pi/\omega$)



13.95. A uniform rod of length L oscillates through small angles about a point a distance x from its c enter. (a) Prove that its angular frequency is $\sqrt{gx/(\frac{L^2}{12}+x^2)}$

(b) Show that its maximum angular frequency occurs when $x = L/\sqrt{12}$

(c) What is the length of the rod if the maximum angular frequency is 2π rad/s?

13.98. (a) What is the change ΔT in the period of a simple pendulum when the acceleration of gravity g changes by Δg? (Hint: The new period $T + \Delta T$ is obtained by substituting $g + \Delta g$ for g:

$$T + \Delta T = 2\pi\sqrt{\frac{L}{g+\Delta g}}$$

To obtain an approximate expression, expand the factor $(g+\Delta g)^{-\frac{1}{2}}$ using the binomial theorem (Appendix B) and keep only the first two terms:

$$(g+\Delta g)^{-\frac{1}{2}} = g^{-\frac{1}{2}} - \frac{1}{2}g^{-\frac{3}{2}}\Delta g + \cdots$$

The other terms contain higher powers of Δg and are very small if Δg is small.) Express your result as the fractional change in period $\Delta T/T$ in terms of the fractional change $\Delta g/g$. (b) A pendulum clock keeps correct time at a point where g = 9.8000 m7s^2, but is found to lose 4.0 s each day at a higher elevation. Use the result of part (a) to find the approximate value of g at this new location.