PHYSICS 191/193

PROBLEMS

1. The x component of vector $\vec{A}$ is -25.0 m and the y component is +40.0 m.

   a) What is the magnitude of $\vec{A}$?
   b) What is the angle between the direction of $\vec{A}$ and the positive direction of x?

2. For the vectors $\vec{a} = (3.0m)\,\hat{i} + (4.0m)\,\hat{j}$ and $\vec{b} = (5.0\,m)\,\hat{i} + (-2.0\ m)\,\hat{j}$, give $\vec{a} + \vec{b}$ in

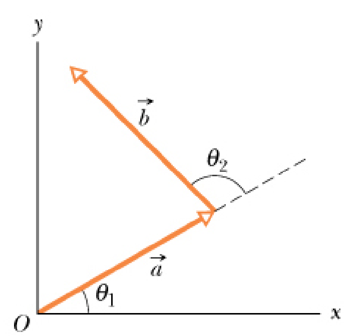
   a) unit-vector notation
   b) magnitude
   c) an angle (relative to $\hat{i}$);

   now give $\vec{b} - \vec{a}$ in

   d) unit-vector notation
   e) magnitude
   f) an angle.

3. The two vectors $\vec{a}$ and $\vec{b}$ in the figure have equal magnitudes of 10.0 m and the angles are $\theta_1 = 30^\circ$ and $\theta_2 = 105^\circ$. Find the

   a) x component of their vector sum $\vec{r}$
   b) y components of their vector sum $\vec{r}$
   c) the magnitude of $\vec{r}$
   d) the angle that $\vec{r}$ makes with the positive direction of the x axis.



4. Three vectors are given by

$$\vec{a} = 3.0\hat{\imath} + 3.0\hat{\jmath} - 2.0\hat{k}$$
$$\vec{b} = -1.0\hat{\imath} - 4.0\hat{\jmath} + 2.0\hat{k}$$
$$\vec{c} = 2.0\hat{\imath} + 2.0\hat{\jmath} + 1.0\hat{k}$$

Find

a) $\vec{a} \cdot (\vec{b} \times \vec{c})$,

b) $\vec{a} \cdot (\vec{b} + \vec{c})$,

c) $\vec{a} \times (\vec{b} + \vec{c})$.

5. Use the definition of scalar product, $\vec{a} \cdot \vec{b} = ab \cos \theta$, and the fact that $\vec{a} \cdot \vec{b} = a_x b_x + a_y b_y + a_z b_z$, calculate the angle between the two vectors given by $\vec{a} = 3.0\hat{\imath} + 3.0\hat{\jmath} + 3.0\hat{k}$ and $\vec{b} = 2.0\hat{\imath} + 1.0\hat{\jmath} + 3.0\hat{k}$.

6. What is the sum of the following four vectors in

$$\vec{A} = (2.00m)\hat{\imath} + (3.00m)\hat{\jmath} \qquad \vec{B}: 4.00m,\ \text{at} + 65.0^\circ$$
$$\vec{C} = (-4.00m)\hat{\imath} - (6.00m)\hat{\jmath} \qquad \vec{D}: 5.00m,\ \text{at} - 235^\circ$$

(a) unit-vector notation
(b) magnitude
(c) angle?

7. a) If a particle's position is given by $x = 4 - 12t + 3t^2$ (where t is in seconds and x is in metres), what is its velocity at $t = 1$ s?

b) Is it moving in the positive or negative direction of x just then?

c) What is its speed just then?

d) Is the speed increasing or decreasing just then? (Try answering the next two questions without further calculation.)

e) Is there ever an instant when the velocity is zero? If so, give the time t; if not, answer no.

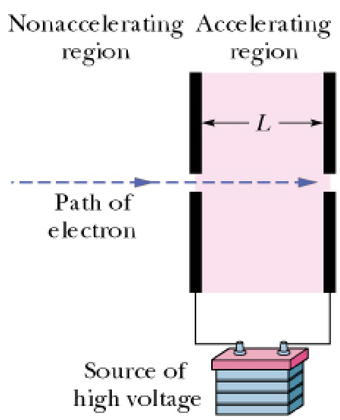
f) Is there a time after $t = 3$ s when the particle is moving in the negative direction of x? If so, give the time t; if not, answer no.

8. The position of a particle moving along the x axis is given in centimetres by $x = 9.75 + 1.50t^3$, where t is in seconds. Calculate

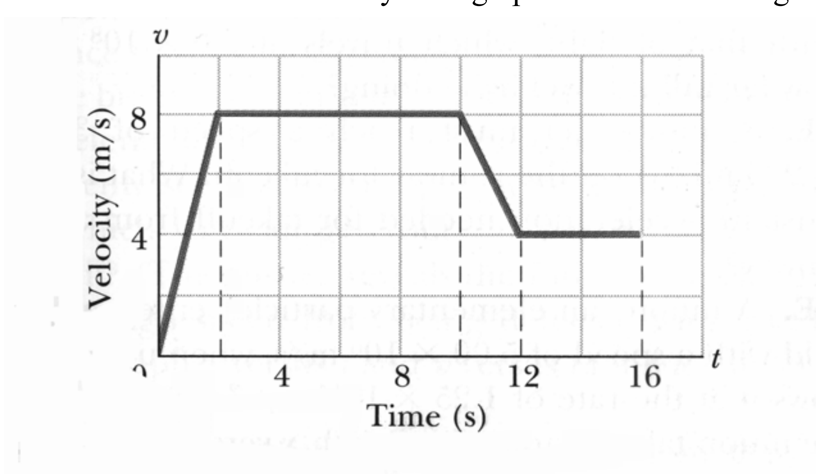
a) the average velocity during the time interval $t = 2.00$ s to $t = 3.00$ s;

b) the instantaneous velocity at $t = 2.00$ s;
c) the instantaneous velocity at $t = 3.00$ s;
d) the instantaneous velocity at $t = 2.50$ s; and
e) the instantaneous velocity when the particle is midway between its positions at $t = 2.00$ s and $t = 3.00$ s.
f) Graph x versus t and indicate your answers graphically.

9. An electron with initial velocity $v_0 = 1.50 \times 10^5\ m/s$ enters a region of length $L = 1.00$ cm where it is electrically accelerated (see figure). It emerges with $v = 5.70 \times 10^6\ m/s$. What is its acceleration, assumed constant? (Such a process occurs in old-fashion television sets.)



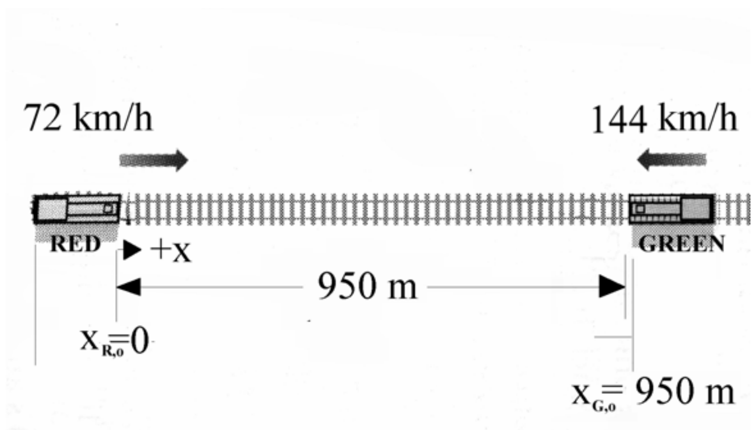
10. How far does the runner whose velocity-time graph is shown in the figure travel in 16 s?



11. At the instant the traffic light turns green, an automobile starts with a constant acceleration a of 2.2 m/s^2. At the same instant a truck, traveling with a constant speed of 9.5 m/s, overtakes and passes the automobile.

a) How far beyond the traffic signal will the automobile overtake the truck?
b) How fast will the automobile be traveling at that instant?

12. A red train traveling at 72 km/h and a green train traveling at 144 km/h are headed toward each other along a straight, level track. When they are 950 m apart, each engineer sees the other's train and applies the brakes. The brakes slow each train at the rate of 1.0 m/s^2. Is there a collision? If so, answer yes and give the speed of the red train and the speed of the green train at impact, respectively. If not, answer no and give the separation between the trains when they stop.



13. A person throws a stone vertically downward with an initial speed of 12.0 m/s from the roof of a building 30.0 m above the ground.

a) How long does it take the stone to reach the ground?
b) What is the speed of the stone at impact?

14. A parachutist bails out and freely falls 50 m. Then the parachute opens, and thereafter she decelerates at 2.0 m/s2. She reaches the ground with a speed of 3.0 m/s.

a) How long is the parachutist in the air?
b) At what height does her fall begin?

15. An electron's position vector is given by $\vec{r} = 3.00t\hat{i} - 4.00t^2\hat{j} + 2.00\hat{k}$, with t in seconds and $\vec{r}$ in metres.

a) In unit-vector notation, what is the electron's velocity $\vec{v}(t)$?
b) At $t = 2.00$ s, what is $\vec{v}$ in unit-vector notation?

c) What is the distance of the electron from the origin at 2.00 s?
d) What is the angle of its velocity vector at 2.00 s relative to the direction of the $+x$ axis?

16. A soccer ball is kicked from the ground with an initial speed of 19.5 m/s at an upward angle of 45˚. A player 55 m away in the direction of the kick starts running to meet the ball at that instant. What must be his average speed if he is to meet the ball just before it hits the ground?

17. During a tennis match, a player serves the ball at 23.6 m/s, with the center of the ball leaving the racquet horizontally 2.37 m above the court surface. The net is 12 m away and 0.90 m high. When the ball reaches the net,

a) does the ball clear it, and
b) what is the distance between the center of the ball and the top of the net?

Suppose that, instead, the ball is served as before but now it leaves the racquet at 5.00˚ below the horizontal. When the ball reaches the net,
c) does the ball clear it, and
d) what now is the distance between the center of the ball and the top of the net?

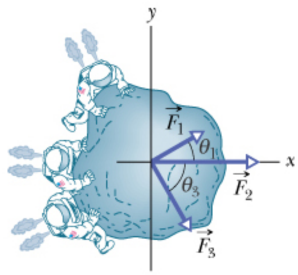
18. The fast French train known as the TGV (Train à Grande Vitesse) has a scheduled average speed of 216 km/h.

a) If the train goes around a curve at that speed and the magnitude of the acceleration experienced by the passengers is to be limited to 0.050g, what is the smallest radius of curvature for the track that can be tolerated?
b) At what speed must the train go around a curve with a 1.00 km radius to be at the acceleration limit?

19. An electron having an initial horizontal velocity of magnitude 1.00×10^9 cm/s travels into the region between two horizontal metal plates that are electrically charged. In that region, the electron travels a horizontal distance of 2.00 cm and has a constant downward acceleration of magnitude 1.00×10^{17} cm/s^2 due to the charged plates. Find

a) the time the electron takes to travel the 2.00 cm,
b) the vertical distance it travels during that time
c) the magnitude of the horizontal velocity component as it emerges from the region
d) the magnitude of the vertical velocity component as it emerges from the region.

20. Three astronauts, propelled by jet backpacks, push and guide a 120 kg asteroid toward a processing dock, exerting the forces shown in the figure with magnitudes and directions: $F_1 = 32$ N, $F_2 = 55$ N, $F_3 = 41$ N, $\theta_1 = 30^\circ$, and $\theta_3 = 60^\circ$. What is the asteroid's acceleration



a) in unit-vector notation
b) its magnitude
c) the direction relative to the +*x* axis?

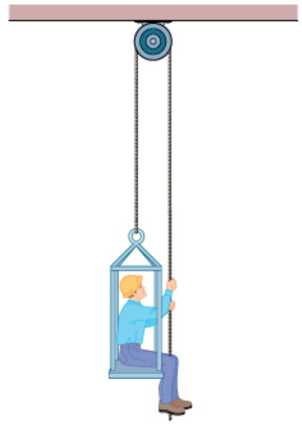
21. A block is projected up a frictionless inclined plane with initial speed $v_o = 3.50$ m/s. The angle of incline is $\theta = 32.0^\circ$.

a) How far up the plane does the block go?
b) How long does it take to get there?
c) What is the speed when it gets back to the bottom?

22. A sphere of mass 3.0×10^{-4} kg is suspended from a cord. A steady horizontal breeze pushes the sphere so that the cord makes a constant angle of 37° with the vertical. Find

a) the push magnitude and
b) the tension in the cord.

23. The figure shows a man sitting in a bosun's chair that dangles from a massless rope, which runs over a massless, frictionless pulley and back down to the man's hand. The combined mass of man and chair is 95.0 kg. With what force magnitude must the man pull on the rope if he is to rise

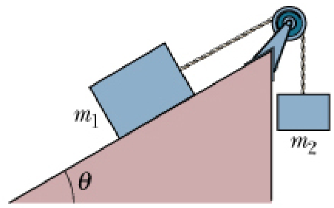


a) with a constant velocity
b) with an upward acceleration of 1.30 m/s^2?

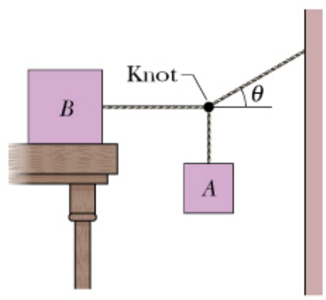
If the rope on the right extends to the ground and is pulled by a co-worker, with what force magnitude must the co-worker pull for the man to rise
c) with a constant velocity
d) with an upward acceleration of 1.30 m/s^2?

What is the magnitude of the force on the ceiling from the pulley system in
e) part a
f) part b
g) part c
h) part d?

24. A block of mass m_1 = 3.70 kg on a frictionless plane inclined at angle θ = 30.0˚ is connected by a cord over a massless, frictionless pulley to a second block of mass m_2 = 2.30 kg hanging vertically (see figure). What are
a) the magnitude of the acceleration of each block
b) the direction of the acceleration of the hanging block
c) the tension in the cord?

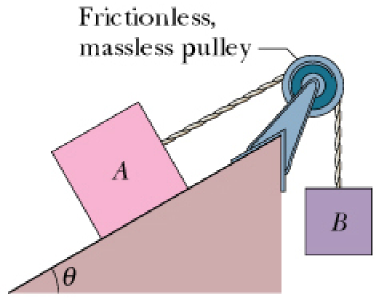


25. Block *B* in the figure weighs 711 N. The coefficient of static friction between block and table is 0.25; angle θ is 30˚; assume that the cord between *B* and the knot is horizontal. Find the maximum weight of block *A* for which the system will be stationary.



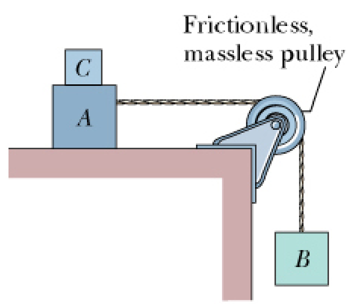
26. Body *A* in the figure weighs 102 N, and body *B* weighs 32 N. The coefficients of friction between *A* and the incline are $\mu_s = 0.56$ and $\mu_k = 0.25$. Angle θ is 40˚. Let the positive direction of an *x* axis be up (and parallel to) the incline. In unit-vector notation, what is the acceleration of *A* if *A* is initially

a) at rest (i.e., is the force of static friction large enough to prevent any acceleration?),
b) moving up the incline,
c) moving down the incline?



27. In the figure below, blocks *A* and *B* have weights of 44 N and 22 N, respectively.

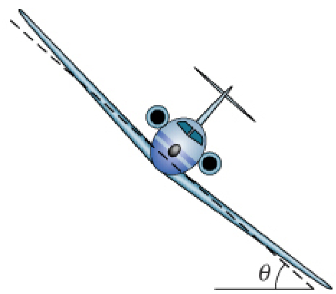
   a) Determine the minimum weight of block *C* to keep *A* from sliding if μ_s between *A* and the table is 0.20.
   b) Block *C* suddenly is lifted off *A*. What is the acceleration of block *A* if μ_k between *A* and the table is 0.15?



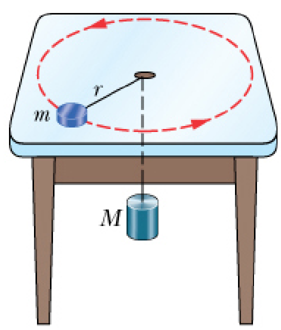
28. A 110 g hockey puck sent sliding over ice is stopped in 15 m by the frictional force on it from the ice.

   a) If its initial speed is 6.0 m/s, what is the magnitude of the frictional force?
   b) What is the coefficient of friction between the puck and the ice?

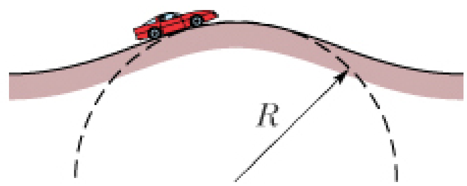
29. An airplane is flying in a horizontal circle at a speed of 480 km/h (see figure). If its wings are titled at angle θ = 40˚ to the horizontal, what is the radius of the circle in which the plane is flying? Assume that the required force is provided entirely by an "aerodynamic lift" that is perpendicular to the wing surface.



30. A puck of mass $m = 1.50$ kg slides in a circle of radius $r = 20.0$ cm on a frictionless table while attached to a hanging cylinder of mass $M = 2.50$ kg by a cord through a hole in the table (see figure). What (tangential) speed keeps the cylinder at rest?



31. In the figure below, a stuntman drives a car (without negative lift) over the top of a hill, the cross section of which can be approximated by a circle of radius $R = 250$ m. What is the greatest speed at which he can drive without the car leaving the road at the top of the hill?

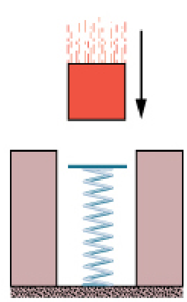


32. When a small 2.0 g coin is placed at a radius of 5.0 cm on a horizontal turntable that makes 3 revolutions in 3.14sec, the coin does not slip. What are

a) the coin's speed
b) the magnitude of its acceleration
c) the direction of its acceleration
d) the magnitude of the frictional force
e) the direction of the frictional force

The coin is on the verge of slipping if it is placed at a radius of 10cm.
f) What is the coefficient of static friction (μ_s) between the coin and the turntable?

33. A 250 g block is dropped onto a relaxed vertical spring that has a spring constant of k = 2.5 N/cm (see figure). The block becomes attached to the spring and compresses the spring 12 cm before momentarily stopping. While the spring is being compressed, what work is done on the block by



a) the gravitational force on it
b) the spring force

c) What is the speed of the block just before it hits the spring? (Assume that friction is negligible.)
d) If the speed at impact is doubled, what is the maximum compression of the spring?

34. A 45 kg block of ice slides down a frictionless incline 1.5 m long and 0.91 m high. A worker pushes up against the ice, parallel to the incline, so that the block slides down at constant speed.

a) Find the magnitude of the worker's force.

How much work is done on the block by:
b) the worker's force,
c) the gravitational force on the block,
d) the normal force on the block from the surface of the incline
e) the net force on the block?

35. To pull a 50 kg crate across a horizontal frictionless floor, a worker applies a force of 210 N, directed 20° above the horizontal. As the crate moves 3.0 m, what work is done on the crate by

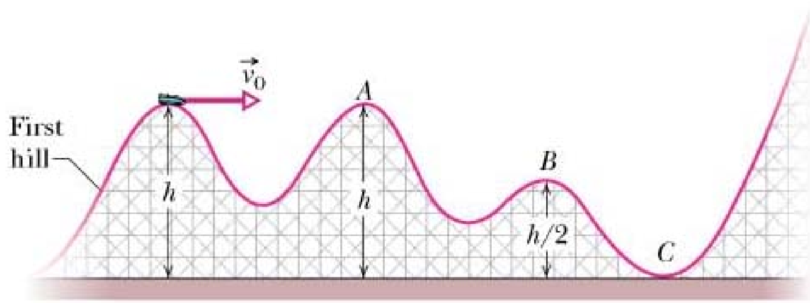
a) the worker's force,
b) the gravitational force on the crate
c) the normal force on the crate from the floor?
d) What is the total work done on the crate?

36. An initially stationary 2.0 kg object accelerates horizontally and uniformly to a speed of 10 m/s in 3.0 s.

a) In that 3.0 s interval, how much work is done on the object by the force accelerating it?
What is the instantaneous power due to that force
b) at the end of the interval
c) at the end of the first half of the interval?

37. In the figure below, a frictionless roller coaster car of mass m = 825 kg tops the first hill with speed v_0 = 17.0 m/s at height h = 42.0 m. How much work does the gravitational force do on the car from that point to

a) point A,
b) point B, and
c) point C?

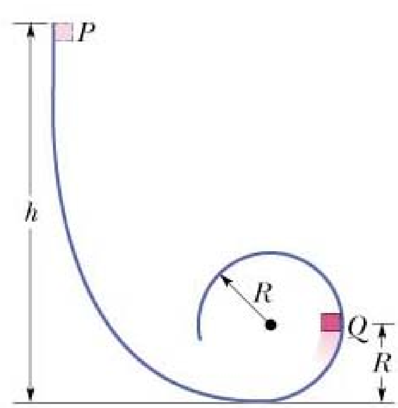


If the gravitational potential energy of the car-Earth system is taken to be zero at C, what is its value when the car is at

d) point B
e) point A?
f) If mass m were doubled, would the change in the gravitational potential energy of the system between points A and B increase, decrease, or remain the same?

38. In the figure, a small block of mass $m = 0.032$ kg can slide along the frictionless loop-the-loop, with loop radius $R = 12$ cm. The block is released from rest at point P, at height $h = 5.0R$, above the bottom of the loop. How much work does the gravitational force do on the block as the block travels from point P to

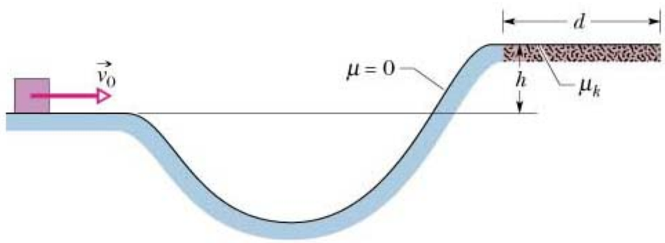
a) point Q
b) the top of the loop?



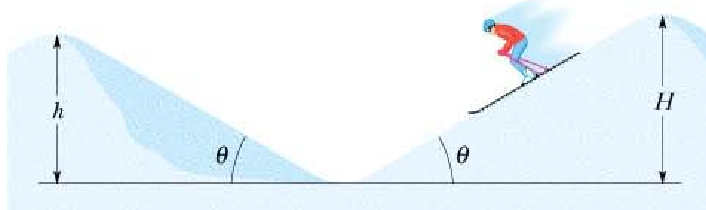
If the gravitational potential energy of the block-Earth system is taken to be zero at the bottom of the loop, what is that potential energy when the block is

c) at point *P*,
d) at point *Q*
e) at the top of the loop?
f) If, instead of merely being released, the block is given some speed downward along the track, do the answers to a) through e) increase, decrease, or remain the same?

39. In the figure below, a block slides along a track from one level to a higher level after passing through an intermediate valley. The track is frictionless until the block reaches the higher level. There a frictional force stops the block in a distance *d*. The block's initial speed v_0 is 6.0 m/s, the height difference *h* is 1.1 m, and μ_k is 0.60. Find *d*.



40. Two snowy peaks are at heights $H = 850$ m and $h = 750$ m above the valley between them. A ski run extends between the peaks, with a total length of 3.2 km and an average slope of $\theta = 30^\circ$ (see figure).



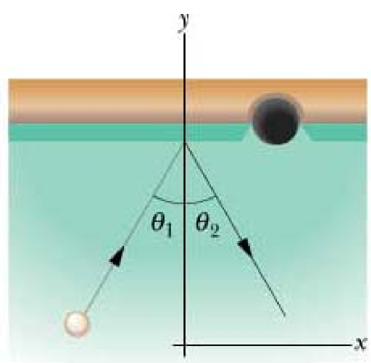
a) A skier starts from rest at the top of the higher peak. At what speed will he arrive at the top of the lower peak if he coasts without using ski poles? Ignore friction.
b) Approximately what coefficient of kinetic friction between snow and skis would make him stop just at the top of the lower peak?

41. Approximately 5.5×10^6 kg of water falls 50 m over Niagara Falls each second.

a) What is the decrease in the gravitational potential energy of the water-Earth system each second?
b) If all this energy could be converted to electrical energy (it cannot be), at what rate would electrical energy be supplied? (The mass of 1 m^3 of water is 1000 kg).
c) If the electrical energy were sold at \$0.01 per kW·hr (kilowatt-hour), what would be the yearly income?

42. The figure gives an overhead view of the path taken by a 0.165 kg cue ball as it bounces from a rail of a pool table. The ball's initial speed is 2.00 m/s, and the angle θ_1 is 30.0˚. The bounce reverses the *y* component of the ball's velocity but does not alter the *x* component. What are

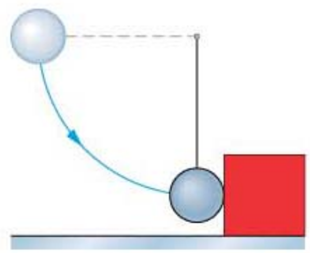
a) angle θ_2 and
b) the change in the ball's linear momentum in unit-vector notation? (The fact that the ball rolls is irrelevant to the problem.)



43. A steel ball of mass 0.500 kg is fastened to a cord that is 70.0 cm long and fixed at the far end. The ball is then released when the cord is horizontal (see figure). At the bottom of

its path, the ball strikes a 2.50 kg steel block initially at rest on a frictionless surface. The collision is elastic. Find

a) the speed of the ball and
b) the speed of the block, both just after the collision.

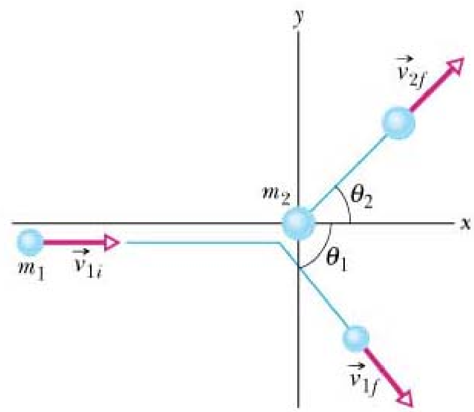


44. An atomic nucleus at rest at the origin of an *x-y* coordinate system transforms into three particles. Particle 1, mass 16.7 × 10^{-27} kg, moves away from the origin at a velocity $(6.00\times10^{6}\text{ m/s})\hat{i}$; particle 2, mass 8.35 × 10^{-27} kg, moves away at velocity $-8.00\times10^{6}\text{ m/s})\hat{j}$.

a) In unit-vector notation what is the linear momentum of the third particle, mass 11.7 × 10^{-27} kg?
b) How much kinetic energy appears in this transformation?

45. In the arrangement of the figure, billiard ball 1 moving at a speed of 2.2 m/s undergoes a glancing collision with identical billiard ball 2 that is at rest. After the collision, ball 2 moves at speed 1.1 m/s, at an angle of $\theta_2 = 60^\circ$. What are

a) the magnitude and
b) the direction of the velocity of ball 1 after the collision?
c) Do the given data suggest the collision is elastic or inelastic?



46. Starting from rest, a disk rotates about its central axis with constant angular acceleration. In 5.0 s, it rotates 25 radians. During that time, what are the magnitudes of

a) the angular acceleration and
b) the average angular velocity?
c) What is the instantaneous angular velocity of the disk at the end of the 5.0 s?
d) With the angular acceleration unchanged, through what additional angle will the disk turn during the next 5.0 s?

47. A flywheel with a diameter of 1.20 m is rotating at an angular speed of 200 rev/min.

a) What is the angular speed of the flywheel in radians per second?
b) What is the linear speed of a point on the rim of the flywheel?
c) What constant angular acceleration (in revolutions per minute-squared) will increase the wheel's angular speed to 1000 rev/min in 60.0 s?
d) How many revolutions does the wheel make during the 60.0 s?

48. A record turntable is rotating at 33 1/3 rev/min. A watermelon seed is on the turntable 6.0 cm from the axis of rotation.

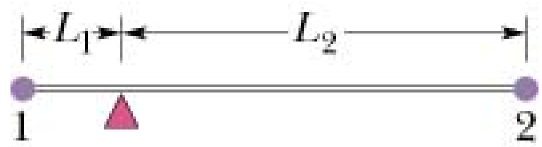
a) Calculate the acceleration of the seed, assuming that it does not slip.
b) What is the minimum value of the coefficient of static friction between the seed and the turntable if the seed is not to slip?
c) Suppose that the turntable achieves its angular speed by starting from rest and undergoing a constant angular acceleration for 0.25 s. Calculate the minimum

coefficient of static friction required for the seed not to slip during the acceleration period.

49. A small ball of mass 0.75 kg is attached to one end of a 1.25 m-long massless rod, and the other end of the rod is hung from a pivot. When the resulting pendulum is 30˚ from the vertical, what is the magnitude of the torque about the pivot?

50. The figure shows particles 1 and 2, each of mass *m*, attached to the ends of a rigid massless rod of length $L_1 + L_2$, with $L_1 = 20$ cm and $L_2 = 80$ cm. The rod is held horizontally on the fulcrum and then released. What are the magnitudes of the initial accelerations of

a) particle 1
b) particle 2?

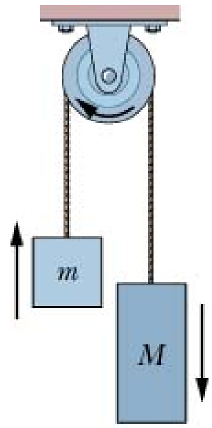


51. In the figure, one block has mass $M = 500$ g, the other has mass $m = 460$ g, and the pulley, which is mounted in horizontal frictionless bearings, has a radius of 5.00 cm. When released from rest, the more massive block falls 75.0 cm in 5.00 s (without the cord slipping on the pulley).

a) What is the magnitude of the block's acceleration?

What is the tension in the part of the cord that supports

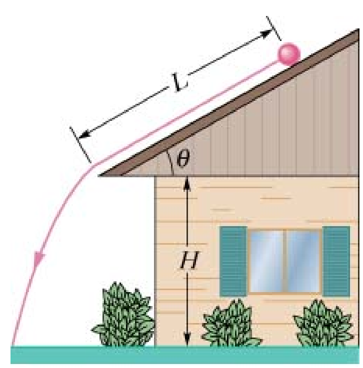
b) the more massive block and
c) the less massive block?
d) What is the magnitude of the pulley's angular acceleration?
e) What is its rotational inertia?



52. A metre stick is held vertically with one end on the floor and is then allowed to fall. Find the speed of the other end just before it hits the floor, assuming that the end on the floor does not slip. (*Hint:* Consider the stick to be a thin rod and use the conservation of energy principle).

53. In the figure, a solid cylinder of radius 10 cm and mass 12 kg starts from rest and rolls without slipping a distance $L = 60$ m down a roof that is inclined at angle $\theta = 30^\circ$.

   a) What is the angular speed of the cylinder about its center as it leaves the roof?
   b) The roof's edge is at height $H = 5.0$ m. How far horizontally from the roof's edge does the cylinder hit the level ground?

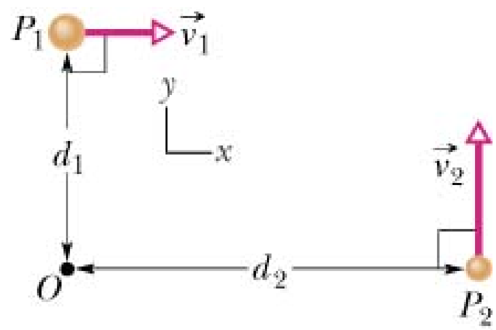


54. The angular momentum of a flywheel having a rotational inertia of 0.140 kg·m^2 about its central axis decreases from 3.00 to 0.800 kg·m^2/s in 1.50 s.

a) What is the magnitude of the average torque acting on the flywheel about its central axis during this period?
b) Assuming a constant angular acceleration, through what angle does the flywheel turn?
c) How much work is done on the wheel?
d) What is the average power of the flywheel?

55. In the instant shown in the figure, two particles move in an xy plane. Particle P_1 has mass 6.5 kg and speed v_1 = 2.2 m/s, and it is at distance d_1 = 1.5 m from point O. Particle P_2 has mass 3.1 kg and speed v_2 = 3.6 m/s and it is at distance d_2 = 2.8 m from point O. What are the

a) magnitude and
b) direction of the net angular momentum of the two particles about O?



56. A 3.0 kg particle with velocity $\vec{v} = (5.0\,\text{m/s})\hat{i} - (6.0\,\text{m/s})\hat{j}$ is at x = 3.0 m, y = 8.0 m. It is pulled by a 7.0 N force in the negative x direction. About the origin, what are

a) the particle's angular momentum,
b) the torque acting on the particle
c) the rate at which the angular momentum is changing?

57. The rotational inertia of a collapsing spinning star drops to 1/3 its initial value. What is the ratio of the new rotational kinetic energy to the initial rotational kinetic energy?

58. In the figure below, a small 50 g block slides down a frictionless surface through height h = 20 cm and then sticks to a uniform rod of mass 100 g and length 40 cm.

The rod pivots about point O through angle θ before momentarily stopping. Find θ.