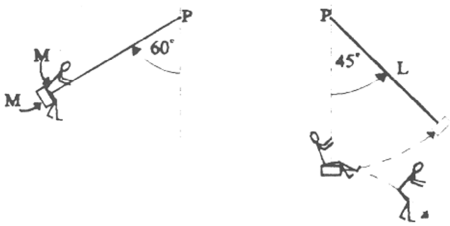
AP PHYSICS C - 1981- MECHANICS

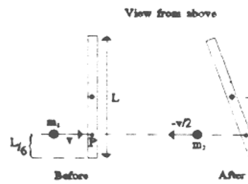
1. A block mass m, acted on by a force of magnitude F directed horizontally to the right as shown below, slides up an inclined plane that makes an angle θ with the horizontal. The coefficient of sliding friction between the block and the plane is μ.
   a. On the diagram of the block to the right, draw and label all the forces that act on the block as it slides up the plane.

   b. Develop an expression in terms of μ, θ, F, m, and g, for the block's acceleration up the plane.
   c. Develop an expression for the magnitude of the force F that will allow the block to slide up the plane with constant velocity. What relation must θ and μ satisfy in order for this solution to be physically meaningful?

2. A swing seat of mass M is connected to a fixed point P by a massless cord of length L. A child also of mass M sits on the seat and begins to swing with zero velocity at a position at which the cord makes a 60° angle with the vertical as shown below. The swing continues down until the cord is exactly vertical at which time the child jumps off in a horizontal direction. The swing continues in the same direction until the cord makes an angle of 45° with the vertical as shown; at that point it begins to swing in the reverse direction. With what velocity relative to the ground did the child leave the swing?

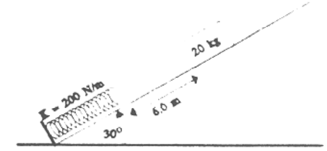


3. A thin uniform rod of mass M_1 and length L is initially at rest on a frictionless horizontal surface. The moment of inertia of the rod about its center of mass is $^1/_{12}M_1L^2$. As shown below, the rod is struck at point P by a mass m_2 whose initial velocity v_o is perpendicular to the rod. After the collision, mass m_2 has velocity $-^1/_2v_o$ as shown in Figure IV. Answer the following in terms of the symbols given.
   a. Using the principle of conservation of linear momentum, determine the velocity v_f of the center of mass of the rod after the collision.
   b. Using the principle of conservation of angular momentum, determine the angular velocity ω of the rod about its center after the collision.
   c. Determine the change in kinetic energy of the system resulting from the collision.

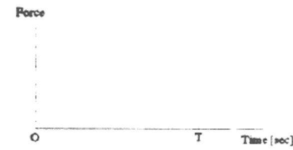


AP PHYSICS C - 1982 - MECHANICS

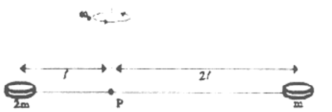
1. A 20 kg mass, released from rest, slides 6.0 meters down a frictionless plane inclined at an angle of 30° with the horizontal and strikes a spring of spring constant K = 200 Newtons/meter as shown below. Assume the spring is ideal, that the mass of the spring is negligible, and that mechanical energy is conserved.
   a. Determine the speed of the block just before it strikes the spring.
   b. Determine the distance the spring has been compressed when the block comes to rest.
   c. Is the speed of the block at a maximum at the instant the block strikes the spring. Justify.



2. A car of mass M moves with an initial speed vo on a straight horizontal road. The car is brought to rest by braking in such a way that the speed of the car as a function of time t is given by $v = [v_o^2-(Rt/M)]^{1/2}$, where R is a constant.
   a. Develop an equation that expresses the time rate of change of kinetic energy.
   b. Determine the time T it takes to bring the car to a complete stop.
   c. Develop an equation for the acceleration of the car as a function of time t.
   d. On the axes at the right, sketch the magnitude of the braking force as a function of time t.

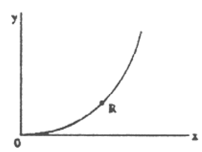


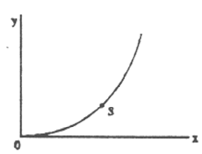
3. A system consists of two small disks, of masses m and 2m, attached to a rod of negligible mass of length 3*l* as shown. The rod is free to turn about a vertical axis through point P. The two disks rest on a rough horizontal surface; the coefficient of friction between the disks and the surface is μ. At time t = 0, the rod has an initial counterclockwise angular velocity ω_o about point P. The system is gradually brought to rest by friction. Develop expressions for the following quantities in terms of μ, m, g, and ω_o.
   a. The initial angular momentum of the system about the axis P.
   b. The frictional torque acting on the system about the axis through P.
   c. The time T at which the system will come to rest.



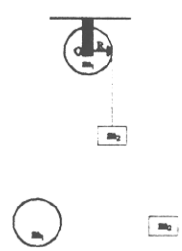
AP PHYSICS C - 1983 - MECHANICS

1. A particle moves along the parabola with equation $y = {^1/_2}\,x^2$ as shown in the diagram to the right.
   a. Suppose the particle moves so that the x-component of its velocity has the constant value v_x = C; that is, x = Ct.
      i. On the diagram indicate the direction of the particle's velocity vector v and acceleration vector a at point R, and label each vector.
      ii. Determine the y-component of the particle's velocity as a function of x.
      iii. Determine the y-component of the particle's acceleration.
   b. Suppose, instead, that the particle moves along the same parabola with a velocity whose x-component is given by $v_x=C/(1+x^2)^{1/2}$.
      i. Show that the particle's speed is constant in this case.
      ii. On the diagram below, indicate the directions of the particle's velocity vector v and acceleration vector a at point S, and label each vector. Explain.

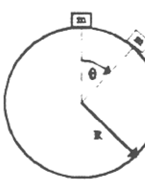




2. A uniform solid cylinder of mass m_1 and radius R is mounted on frictionless bearings about a fixed axis through point O. The moment of inertia of the cylinder about the axis is $I = {^1/_2}\,m_1R^2$. A block of mass m_2, suspended by a cord wrapped around the cylinder as shown is released at time t = 0.
   a. On the diagrams below draw and identify all of the forces acting on the cylinder and block.
   b. In terms of m_1, m_2, R, and g, determine each of the following.
      i. The acceleration of the block.
      ii. The tension in the cord.
      iii. The angular momentum of the disk as a function of time t.

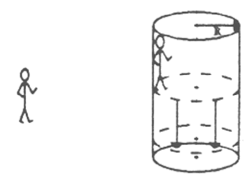


3. A particle of mass m slides down a fixed, frictionless sphere of radius R, starting from rest at the top as shown below.
   a. In terms of m, g, R, and θ, determine each of the following for the particle while it is sliding on the sphere.
      i. The kinetic energy of the particle.
      ii. The centripetal acceleration of the mass.
      iii. The tangential acceleration of the mass.
   b. Determine the value of θ at which the particle leaves the sphere.

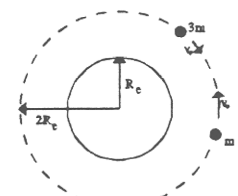


AP PHYSICS C - 1984 - MECHANICS

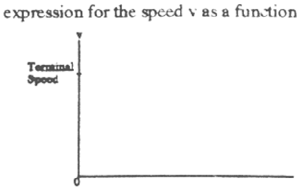
1. An amusement park ride consists of a rotating vertical cylinder with rough canvas walls. The floor is initially about halfway up the cylinder wall as shown in the diagram. After the rider has entered and the cylinder is rotating sufficiently fast, the floor is dropped down, yet the rider does not slide. The rider has a mass of 50 kg, the radius R of the cylinder is 5 meters, the angular velocity of the cylinder when rotating is 2.0 Radians per second, and the coefficient of static friction between the rider and the wall of the cylinder is μ = 0.6.
   a. On the diagram below, draw and identify the forces on the rider when the system is rotating and the floor has dropped down.
   b. Calculate the centripetal force on the rider when the cylinder is rotating and state what provides that force.
   c. Calculate the upward force that keeps the rider from falling when the floor is dropped down and state what provides that force.
   d. At the same rotational speed would a rider of twice the mass slide down the wall? Explain.



2. Two satellites, of masses m and 3m, respectively, are in the same cylindrical orbit about the Earth's center. The Earth has mass M_e and radius R_e. In this orbit, which has a radius $2R_e$, the satellites initially move with the same orbital speed v_o, but in opposite directions.
   a. Calculate the orbital speed vo of the satellites in terms of G, M_e, and R_e.
   b. Assume that the satellites collide head on and stick together. In terms of v_o, find the speed v of the combination immediately after the collision.
   c. Calculate the total mechanical energy of the system immediately after the collision in terms of G, m, M_e, and R_e. Assume that the gravitational potential energy of an object is defined to be zero at an infinite distance form the Earth.

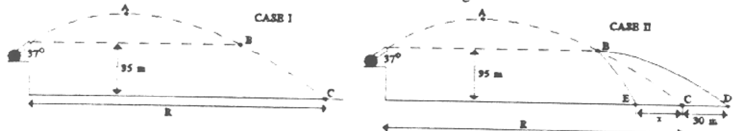


3. A small body of mass m located near the Earth's surface falls from rest in the Earth's gravitational field. Acting on the body is a resistive force of magnitude kmv, where k is a constant and v is the speed of the body.
   a. On the diagram below draw and identify all the forces acting on the body as it falls.
   b. Write the differential equation that represents Newton's Second Law for this situation.
   c. Determine the terminal speed v_t of the body.
   d. Integrate the differential equation once to obtain an expression for the speed v as a function of time t. Use the condition that v = 0 when t = 0.
   e. On the axes to the right draw a graph of the speed v as a function of time t.



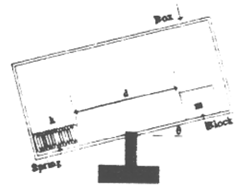
AP PHYSICS C - 1985 - MECHANICS

1. A projectile is launched from the top of a cliff above ground level. At launch the projectile is 35 meters above the base of the cliff and has a velocity of 50 m/s at an angle of 37° above the horizontal. Air resistance is negligible. Consider the following two cases.



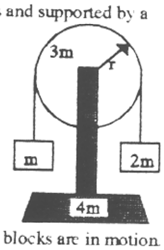
Case I: The projectile follows the path shown by the curved line in the above diagram.
a. Calculate the total time from launch until the projectile hits the ground at point C.
b. Calculate the horizontal distance R that the projectile travels before it hits the ground.
c. Calculate the speed of the projectile at points A, B, and C.
Case II: A small internal charge explodes at point B causing the projectile to separate into two parts of masses 6.0 kg and 10.0 kg. The explosive force on each mass is horizontal and in the plane of the trajectory. The 6.0 kg mass strikes the ground at point D, located 30 meters beyond point C, where the projectile would have landed had it not exploded. The 10 kg mass strikes the ground at point E.
d. Calculate the distance x from C to E.

2. An apparatus to determine the coefficients of friction is shown to the right. The box is slowly rotated counterclockwise. When the box makes an angle θ with the horizontal, the block of mass m just starts to slide and at this instant the box is stopped from rotating. Thus at angle θ, the block slides a distance d, hits the spring of force constant k, and compresses the spring a distance x before coming to rest. In terms of the given quantities, derive expressions for each of the following:



a. μ_s, the coefficient of static friction.
b. ΔE, the loss in total mechanical energy of the block-spring system from the start of the block down the incline to the moment at which it comes to rest on the compressed spring.
c. μ_k, the coefficient of kinetic friction.

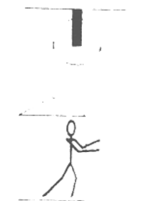
3. A pulley system of mass 3m and radius r is mounted on frictionless bearings and supported by a stand of mass 4m at rest on a table as shown to the right. The moment of inertia of this pulley about its axis is $^3/_2\ mr^2$. Passing over the pulley is a massless cord supporting a block of mass m on the left and a block of mass 2m on the right. The cord does not slip on the pulley, so after the block-pulley system is released from rest, the pulley begins to rotate.



a. On the diagrams to the right draw and label all of the forces acting on each block.
b. Use the symbols identified in part (a) to write each of the following:
i. The equations of translational motion for each block.
ii. The analogous equation for the rotational motion of the pulley.
c. Solve the equations from part (b) for the acceleration of the two blocks.
d. Determine the tension in the segment of the cord attached to mass m.
e. Determine the normal force exerted on the apparatus by the table while the blocks are in motion.

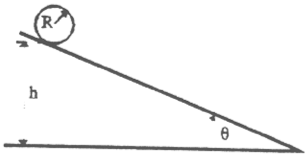
AP PHYSICS C - 1986 - MECHANICS

1. The figure in the diagram at the right shows an 80 kg person standing on a 20 kg platform suspended by a rope passing over a stationary pulley that is free to rotate. The other end of the rope is held by the person. The masses of the rope and pulley are negligible. Assume that friction is negligible, and that the parts of the rope shown remain vertical.



a. If the platform and the person are at rest, what is the tension in the rope?
The person now pulls on the rope so that the acceleration of the person and the platform is 2 m/s² upward.
b. That is the tension in the rope under these conditions?
c. Under these conditions, what is the force exerted by the platform on the person?
After a short time, the person and the platform reach and sustain an upward velocity of 0.4 m/s.
d. Determine the power output of the person required to sustain this velocity.

2. An inclined plane makes an angle of θ with the horizontal. A solid sphere of radius R and mass M is initially at rest in the position shown, such that the lowest point of the sphere is a vertical height h above the base of the plane. The sphere is released and rolls down the plane without slipping. The moment of inertia of the sphere about an axis through the center is $^2/_5\ MR^2$. Express your answer in terms of M, R, h, g, and θ.

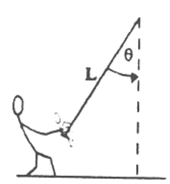


a. Determine the following for the sphere when it is at the bottom of the plane.
i. Its translational kinetic energy.
ii. Its rotational kinetic energy.
b. Determine the following for the sphere when it is on the plane.
i. Its linear acceleration.
ii. The magnitude of the frictional force acting on it.
The solid sphere is replaced by a hollow sphere of identical radius R and mass M. The hollow sphere, which is released from the same location as the solid sphere, rolls down the incline without slipping.
c. What is the total kinetic energy of the hollow sphere at the bottom of the plane?
d. State whether the rotational kinetic energy of the hollow sphere is greater than, less than, or equal to that of the solid sphere at the bottom of the plane. Justify.

3. A special spring is constructed in which the restoring force is in the opposite direction to the displacement, but is proportional to the cube of the displacement; $F = -kx^3$. This spring is placed on a horizontal frictionless surface. One end of the spring is fixed, and the other end is fastened to a mass M. The mass is moved so that the spring is stretched a distance A and then released. Determine each of the following in terms of k, A, and M.
a. The potential energy in the spring at the instant the mass is released.
b. The maximum speed of the mass.
c. The displacement of the mass at the point where the potential energy of the spring and the kinetic energy of the mass are equal.
The amplitude of the oscillation is now increased.
d. State whether the period of the oscillation increases, decreases, or remains the same. Justify.

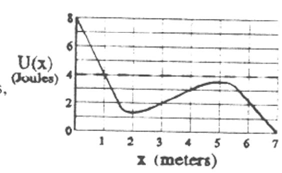
AP PHYSICS C - 1987 - MECHANICS

1. An adult exerts a horizontal force on a swing that is suspended by a rope of length L, holding it at an angle θ with the vertical. The child in the swing has a weight W and dimensions that are negligible compared to L. The weights of the rope and seat are negligible. In terms of W and θ, determine

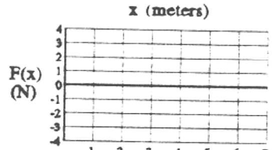


a. the tension in the rope;
b. the horizontal force exerted by the adult.
The Adult releases the swing from rest. In terms of W and θ, determine
c. the tension in the rope just after the release (the swing is instantaneously at rest);
d. the tension in the rope as the swing passes through the lowest point.

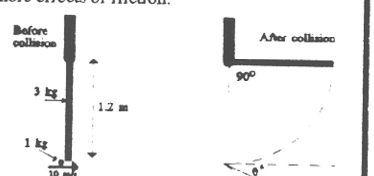
2. The following graph shows the potential energy U(x) of a particle as a function of its position x.



a. Identify all points of equilibrium for this particle.
Suppose the particle has a constant total energy of 4.0 Joules, as shown by the dashed line on the graph.
b. Determine the kinetic energy of the particle at the following positions
i. x = 2.0 m
ii. x = 4.0 m
c. Can the particle reach the position x = 0.5 m ? Explain.
d. Can the particle reach the position x = 5.0 m ? Explain.
e. On the grid to the right, carefully draw a graph of the conservative force acting on the particle as a function of x, for 0<x<7 meters.

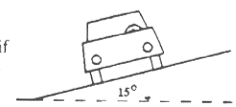


3. A 1.0 kg object is moving horizontally with a velocity of 10 m/s when it makes a glancing collision with the lower end of a bar that was hanging vertically at rest before the collision. For the system consisting of the object and bar, linear momentum is not conserved in this collision, but kinetic energy is conserved. The bar, which has a length L of 1.2 meters and a mass of 3.0 kg, is pivoted about the upper end. Immediately after the collision the object moves with a speed c at an angle θ relative to its original direction. The bar swings freely, and after the collision reaches a maximum angle of 90° with respect to the vertical. The moment of inertia of the bar about the pivot is $I_{bar} = mL^2/3$. Ignore effects of friction.
a. Determine the angular velocity of the bar immediately after the collision.
b. Determine the speed v of the 1 kg object immediately after the collision.
c. Determine the magnitude of the angular momentum of the object about the pivot just before the collision.
d. Determine the angle θ.



AP PHYSICS C - 1988 - MECHANICS

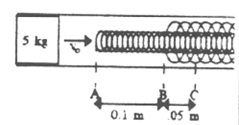
1. A highway curve that has a radius of 100 meters is banked at an angle of 15° as shown.



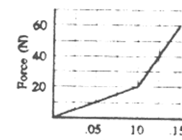
a. Determine the vehicle speed for which this curve is appropriate if there is no friction between the road and the tires of this vehicle.
On a dry day when friction is present, automobile successfully negotiates the curve at a speed of 25 m/s.
b. On the diagram at the right draw and label all of the forces acting on the automobile.

c. Determine the minimum value of the coefficient of friction necessary to keep this automobile from sliding as it goes around the curve.

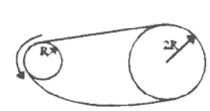
2. A 5 kg object initially slides with a speed of vo in a hollow frictionless pipe. The end of the pipe contains two springs, one nested within the other as shown. The object makes contact with the inner spring at point B and then moves an additional 0.05 meter before coming to rest at point C. The graph shows the magnitude of the force exerted on the object by the springs as a function of the object's distance from point A.



a. Calculate the spring constant for the inner spring.
b. Calculate the decrease in kinetic energy of the object as it moves from point A to point B.
c. Calculate the additional decrease in kinetic energy of the object as it moves from point B to point C.
d. Calculate the initial speed of the object.
e. Calculate the spring constant of the outer spring.

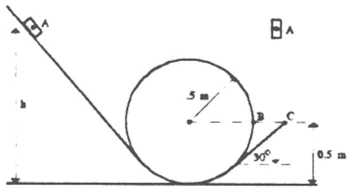


3. The two uniform disks shown in the diagram have equal mass, and each can rotate on frictionless bearings about a fixed axis through its center. The smaller disk has radius R and moment of inertia I about its axis. The larger disk has a radius 2R.
a. Determine the moment of inertia of the larger disk about its axis in terms of I.
The two disks are then linked as shown by a light chain that cannot slip. They are at rest when, at time t = 0, a student applies a torque to the smaller disk, and it rotates counterclockwise with constant angular acceleration α. Assume that the mass of the chain and the tension in the lower part of the chain are negligible. In terms of I, R, α, and t, determine each of the following.
b. The angular acceleration of the larger disk.
c. The tension in the upper part of the chain.
d. The torque that the student applied to the smaller disk.
e. The rotational kinetic energy of the smaller disk as a function of time.



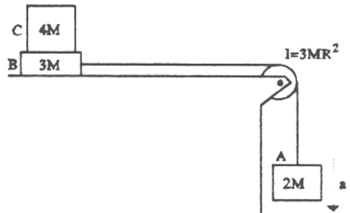
AP PHYSICS C - 1989 - MECHANICS

1. A 0.1 kg block is released from rest at point A as shown in the diagram, a vertical distance h above the ground. It slides down an inclined track, around a circular loop of radius 0.5 meter, then up another incline that forms an angle of 30° with the horizontal. The block slides off the track with a speed of 4.0 meters per second at point C, which is a height of 0.5 meter above the ground. Assume the entire track to be frictionless and air resistance to be negligible.



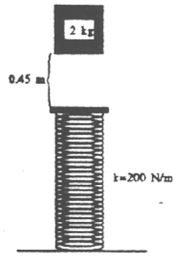
   a. Determine the height h.
   b. On the figure to the right, draw and label all the forces acting on the block when it is at point B, which is 0.5 meter above the ground.
   c. Determine the magnitude of the force exerted by the track on the block when it is at point B.
   d. Determine the maximum height above the ground attained by the block after it leaves the track.
   e. Another track that has the same configuration, but is NOT frictionless, is used. With this track it is found that if the block is to reach point C with a speed of 4.0 m/s, the height h must be 2.0 meters. Determine the work done by the frictional force.

2. Block A of mass 2M hangs from a cord that passes over a pulley and is connected to block B of mass 3M that is free to move on a frictionless horizontal surface as shown. The pulley is a disk with frictionless bearings, having a radius R and moment of inertia $3MR^2$. Block C of mass 4M is on top of block B. The surface between blocks B and C is NOT frictionless. Shortly after the system is released from rest, block A moves with a downward acceleration a, and the two blocks on the table move relative to each other. In terms of M, g, and a, determine the



   a. tension T_v in the vertical section of the cord.
   b. tension T_h in the horizontal section of the cord.
   If a = 2 m/s², determine the
   c. coefficient of kinetic friction between blocks B and C.
   d. acceleration of block C.

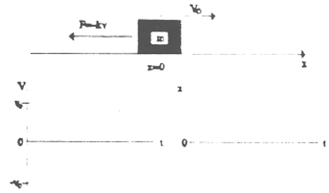
3. A 2.0 kg block is dropped from a height of 0.45 meters above an uncompressed spring, as shown. The spring has an elastic constant of 200 N/m and negligible mass. The block strikes the end of the spring and sticks to it.



   a. Determine the speed of the block at the instant it hits the end of the spring.
   b. Determine the period of the simple harmonic motion that ensues.
   c. Determine the distance that the spring is compressed at the instant the speed of the block is maximum.
   d. Determine the maximum compression of the spring.
   e. Determine the amplitude of the simple harmonic motion.

AP PHYSICS C - 1990 - MECHANICS

1. An object of mass m moving along the x-axis with velocity v is slowed by a force F = -kv, where k is a constant. At time t = 0, the object has velocity v_o at position x = 0 as shown.



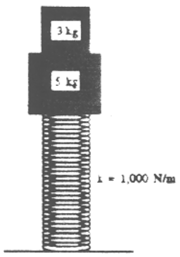
   a. What is the initial acceleration (magnitude and direction) produced by the resistance force?
   b. Derive an equation for the object's velocity as a function of time t, and sketch this function on the axes provided. Let a velocity directed to the right be considered positive.
   c. Derive an equation for the distance the object travels as a function of time t and sketch this function on the axes provided.
   d. Determine the distance the object travels from t = 0 to t = ∞.

2. A block of mass m slides up the incline shown above with an initial speed v_o in the position shown.

   a. If the incline is frictionless, determine the maximum height H to which the block will rise, in terms of the given quantities and appropriate constants.
   b. If the incline is rough with coefficient of sliding friction m, determine the maximum height to which the block will rise in terms of H and the given quantities.
   A thin hoop of mass m and radius R moves up the incline shown with an initial speed v_o in the position shown.

   c. If the incline and rough and the hoop rolls up the incline without slipping, determine the maximum height to which the hoop will rise in terms of H and the given quantities.
   d. If the incline is frictionless, determine the maximum height to which the hoop will rise in terms of H and the given quantities.

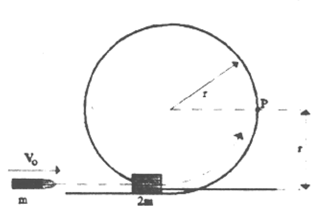
3. A 5.0 kg block is fastened to a vertical spring that has a spring constant of 1,000 N/m. A 3.0 kg block rests on top of the 5.0 kg block ass shown.



   a. When the blocks are at rest, how much is the spring compressed from its original length?
   The blocks are now pushed down and released so that they oscillate.
   b. Determine the frequency of this oscillation.
   c. Determine the magnitude of the maximum acceleration that the blocks can attain and still remain in contact at all times.
   d. How far can the spring be compressed beyond the compression in part (a) without causing the blocks to exceed the acceleration value in part (c)?
   e. Determine the maximum speed of the blocks if the spring is compressed the distance found in part (d).

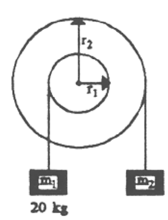
AP PHYSICS C - 1991 - MECHANICS

1. A small block of mass 2m initially at rest on a track at the bottom of the circular, vertical loop-the-loop as shown, which has a radius r. The surface contact between the block and the loop is frictionless. A bullet of mass m strikes the block horizontally with initial speed vo and remains embedded in the block as the block and bullet circle the loop. Determine each of the following in terms of m, v_o, r, and g.



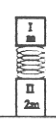
   a. The speed of the block and bullet immediately after impact.
   b. The kinetic energy of the block and bullet when they reach point P on the loop.
   c. The minimum initial speed v_{min} of the bullet is the block and bullet are to successfully execute a complete circuit of the loop.

2. Two masses, m_1 and m_2, are connected by light cables to the perimeters of two cylinders of radii r_1 and r_2, respectively, as shown. The cylinders are rigidly connected to each other but are free to rotate without friction on a common axle. The moment of inertia of the pair of cylinders is I = 45 kgm². Also r_1 = 0.5 meter, r_2 = 1.5 meter and m_1 = 20 kg.



   a. Determine m_2 such that the system will remain at equilibrium.
   The mass m_2 is removed and the system is released from rest.
   b. Determine the angular acceleration of the cylinders.
   c. Determine the tension in the cable supporting m_1.
   d. Determine the linear speed of m_1 at the time it has descended 1.0 meter.

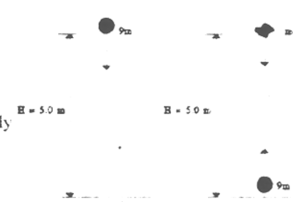
3. The two blocks shown in the diagram have masses m and 2m, respectively. Block II has an ideal massless spring attached to one side. When block I is placed on the spring as shown, the spring is compressed a distance D at equilibrium. Express your answer to all parts of the question in terms of the given quantities and physical constants.



   a. Determine the spring constant of the spring.
   Later the blocks are on a frictionless, horizontal surface. Block II is stationary and block I approaches with a speed v_o as shown.
   b. The spring compression is a maximum when the blocks have the same velocity. Briefly explain why this is so.
   c. Determine the maximum compression of the spring during the collision.
   d. Determine the velocity of block II after the collision when block I has again separated from the spring.

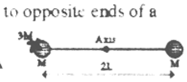
AP PHYSICS C - 1992 - MECHANICS

1. A ball of mass 9m is dropped from rest from a height H = 5.0 m above the ground as shown on the left. It undergoes a perfectly elastic collision with the ground and rebounds. At the instant that the ball rebounds, a small blob of clay of mass m is released from rest from the same original height H, directly above the ball, as shown on the right. The clay bob, which is descending, eventually collides with the ball, which is ascending. Assume g = 10 m/s², that air resistance is negligible, and that the collision process takes negligible time.



   a. Determine the speed of the ball immediately before it strikes the ground.
   b. Determine the time after the release of the clay blob st which the collision takes place.
   c. Determine the height above the ground at which the collision takes place.
   d. Determine the speeds of the ball and the clay immediately before the collision.
   e. If the ball and the clay blob stick together on impact, what is the magnitude and direction of their velocity immediately after the collision?

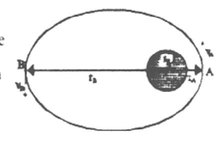
2. Two identical spheres, each of mass M and negligible radius, are fastened to opposite ends of a rod of negligible mass and length 2L. This system is initially at rest with the rod horizontal and is free to rotate about a frictionless, horizontal axis through the center of the rod and perpendicular to the plane of the page. A bug, of mass 3M, lands gently on the sphere on the left. Assume that the size of the bug is small compared to the length of the rod. Express your answers to all parts of the question in terms of M, L, and physical constants.



   a. Determine the torque about the axis immediately after the bug lands.
   b. Determine the acceleration of the bug-sphere-rod system immediately after the bug lands.
   The bug-sphere-rod system swings about the axis. At the instant that the rod is vertical, as shown, determine each of the following.

   c. The angular speed of the bug. d. The angular momentum of the system.
   e. The magnitude and direction of the force that must be exerted on the bug by the sphere to keep the bug from being thrown off the sphere.

3. A spacecraft of mass 1,000 kg is in an elliptical orbit about the Earth, as shown. At point A the spacecraft is at a distance $r_a = 1.2 \times 10^7$ meters from the center of the Earth and its velocity, of magnitude $v_a = 7.1 \times 10^3$ m/s, is perpendicular to the line connecting the center of the Earth to the spacecraft. The mass and radius of the Earth are $M_E = 6.0 \times 10^{24}$ kg and $r_E = 6.4 \times 10^6$ m, respectively. Determine each of the following for the spacecraft when it is at point A.
   a. The total mechanical energy of the spacecraft, assuming that the gravitational potential energy is zero at infinity.
   b. The magnitude of the angular momentum of the spacecraft about the center of the Earth.



   Later the spacecraft is at point B at a distance of $r_B = 3.6 \times 10^7$ m from the center of the Earth.
   c. Determine the speed v_B of the spacecraft at point B.
   Suppose that a different spacecraft is at point A, a distance $r_A = 1.2 \times 10^7$ m from the center of the Earth. Determine each of the following.
   d. The speed of the spacecraft if it is in a circular orbit.
   e. The minimum speed of the spacecraft at point A if it is to escape completely from the Earth.