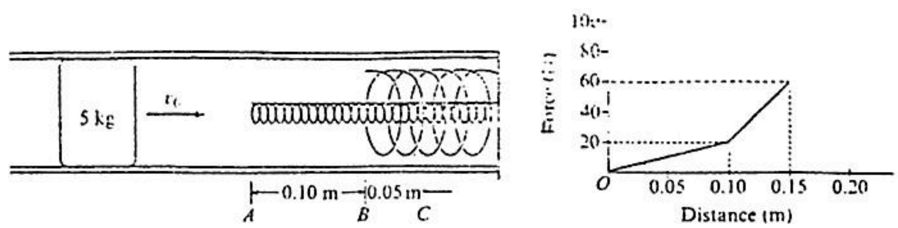
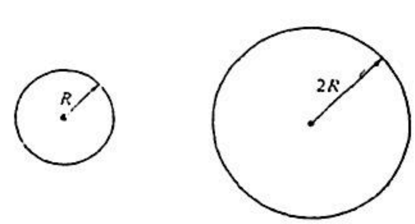
47. A 5-kilogram object initially slides with speed v_o in a hollow frictionless pipe. The end of the pipe contains two springs. one nested inside the other, as shown above. The object makes contact with the inner spring at point A, moves 0.1 meter to make contact with the outer spring at point B, and 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 objects distance from point A.

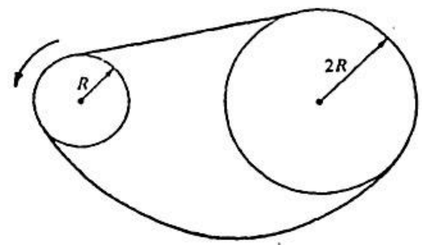


a. Calculate the spring constant for the inner spring.
b. Calculate the decrease in kinetic energy of the object as it moves from point A to point B.
c. Calculate the additional decrease in kinetic energy of the object as it moves from point B to point C.
d. Calculate the initial speed v_o of the object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

48. The two uniform disks shown above have equal mass, and each can rotate on frictionless bearings about a fixed axis through its center. The smaller disk has a 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.

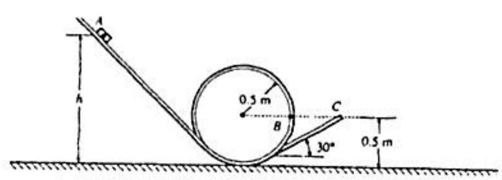


The two disks are then linked as shown below by a light chain that cannot slip. They are at rest when, at time t = 0, a student applies a torque to the smaller disk, and it rotates counterclockwise with constant angular acceleration α. Assume that the mass of the chain and the tension in the lower part of the chain, are negligible.



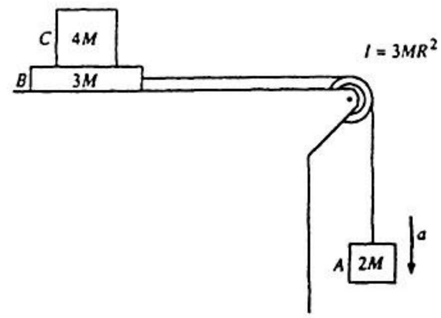
In terms of I, R, α, and t, determine each of the following:
b. The angular acceleration of the larger disk
c. The tension in the upper part of the chain
d. The torque that the student applied to the smaller disk
e. The rotational kinetic energy of the smaller disk as a function of time

49. A 0.1-kilogram block is released from rest at point A as shown above, 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 m/s 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 below, 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 m/s, the height h must be 2 meters. Determine the work done by the frictional force.

50. 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 above. 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

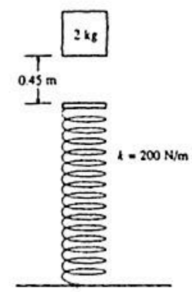
a. tension T_v in the vertical section of the cord

b. tension T_h in the horizontal section of the cord

If a = 2 meters per second squared, determine the

c. coefficient of kinetic friction between blocks B and C

d. acceleration of block C



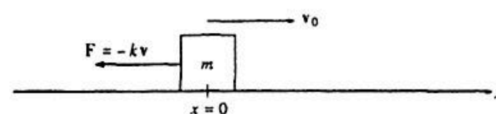
51. A 2-kilogram block is dropped from a height of 0.45 meter above an uncompressed spring, as shown above. The spring has an elastic constant of 200 newtons per meter and negligible mass. The block strikes the end of the spring and sticks to it.

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.

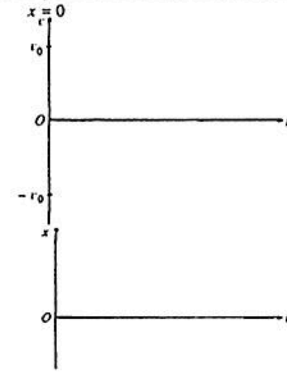
d. Determine the maximum compression of the spring.



52. 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.

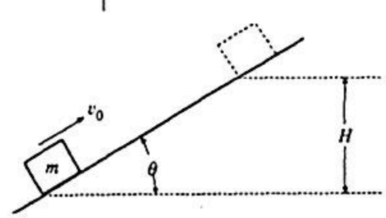
a. What is the initial acceleration (magnitude and direction) produced by the resistance force?

b. Derive an equation for the object's velocity as a function of time t, and sketch this function on the axes below. 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 below.

d. Determine the distance the object travels from t = 0 to t = ∞.



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

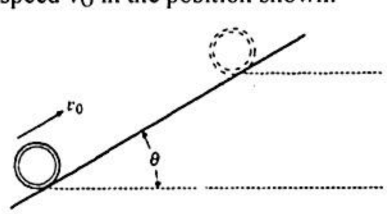
a. If the incline is frictionless, determine the maximum height H to which the block will rise, in terms of the given quantities and appropriate constants.

b. If the incline is rough with coefficient of sliding friction μ, determine the maximum height to which the block will rise in terms of H and the given quantities.

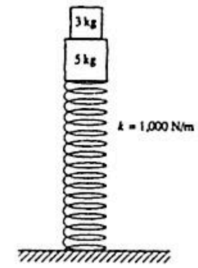
A thin hoop of mass m and radius R moves up the incline shown above with an initial speed v_O in the position shown.

c. If the incline is 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.



54. A 5-kilogram block is fastened to a vertical spring that has a spring constant of 1,000 newtons per meter. A 3-kilogram block rests on top of the 5-kilogram block, as shown above.



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)?

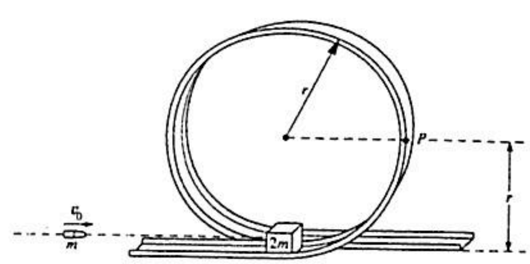
e. Determine the maximum speed of the blocks if the spring is compressed the distance found in part (d).

55. A small block of mass 2m initially rests on a track at the bottom of the circular, vertical loop-the-loop 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 v_o and remains embedded in the block as the block and bullet circle the loop. Determine each of the following in terms of m, v_0 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 if the block and bullet are to successfully execute a complete circuit of the loop



56. 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 in the diagram above. 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 $I = 45\ kgm^2$ Also $r_1 = 0.5$ meter, $r_2 = 1.5$ meters, and $m_1 = 20$ kilograms.

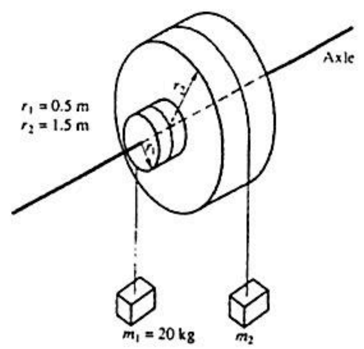
a. Determine m_2 such that the system will remain in equilibrium.

The mass m_2 is removed and the system is released from rest.

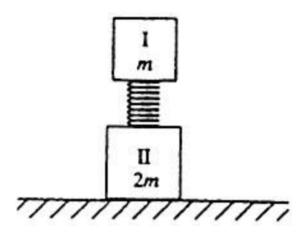
b. Determine the angular acceleration of the cylinders.

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.



57. The two blocks I and II shown above 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.



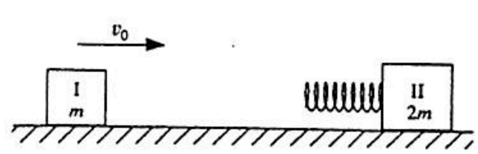
a. Determine the spring constant of the spring

Later the two blocks are on a frictionless, horizontal surface. Block II is stationary and block I approaches with a speed v_o, as shown above.

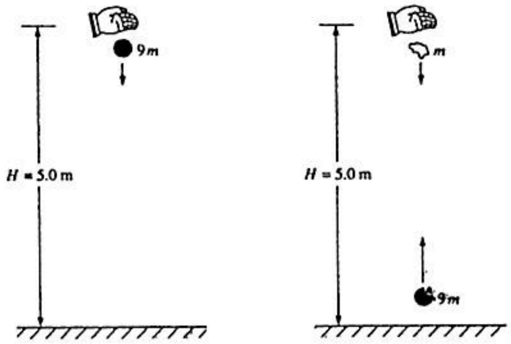
b. The spring compression is a maximum when the blocks have the same velocity. Briefly explain why this is so.

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.

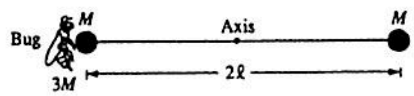


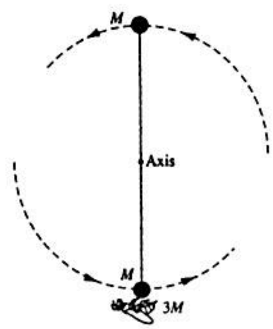
58. A ball of mass 9m is dropped from rest from a height H = 5.0 meters above the ground, as shown above on the left. It undergoes a perfectly elastic collision with the ground and rebounds. At the instant that the ball rebounds, a small blob of clay of mass m is released from rest from the original height H, directly above the ball, as shown above on the right. The clay blob, which is descending, eventually collides with the ball, which is ascending. Assume that $g = 10\ m/s^2$, that air resistance is negligible, and that the collision process takes negligible time.



a. Determine the speed of the ball immediately before it hits the ground.
b. Determine the time after the release of the clay blob at 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 blob 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?

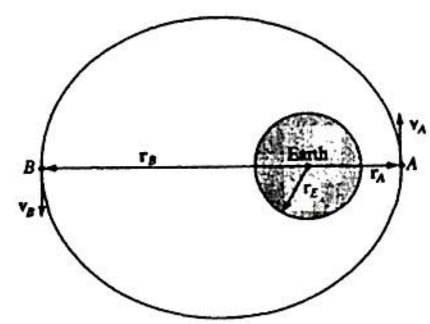
59. Two identical spheres, each of mass M and negligible radius, are fastened to opposite ends of a rod of negligible mass and length $2l$. This system is initially at rest with the rod horizontal, as shown above, and is free to rotate about a frictionless, horizontal axis through the center of the rod 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 on the sphere.
b. Determine the angular acceleration of the rod-spheres-bug system immediately after the bug lands.
The rod-spheres-bug system swings about the axis. At the instant that the rod is vertical, as shown above, 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

60. A spacecraft of mass 1,000 kilograms is in an elliptical orbit about the Earth, as shown above. 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 $V_A = 7.1 \times 10^3$ meters per second, is perpendicular to the line connecting the center of the Earth to the spacecraft. The mass and radius of the Earth are $M_E = 6.0 \times 10^{24}$ kilograms and $r_E = 6.4 \times 10^6$ meters, respectively.
Determine each of the following for the spacecraft when it is at point A .

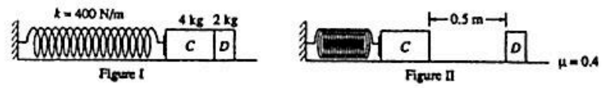


a. The total mechanical energy of the spacecraft, assuming that the gravitational potential energy is zero at an infinite distance from the Earth.
b. The magnitude of the angular momentum of the spacecraft about the center of the Earth.

Later the spacecraft is at point B on the exact opposite side of the orbit at a distance $r_B = 3.6 \times 10^7$ meters from the center of the Earth.
c. Determine the speed v_B of the spacecraft at point B.

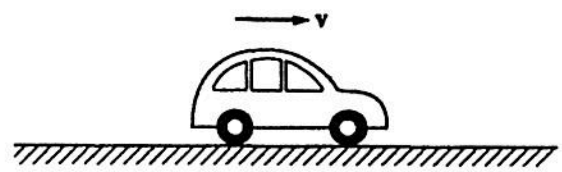
Suppose that a different spacecraft is at point A, a distance $r_A = 1.2 \times 10^7$ meters from the center of the Earth. Determine each of the following.
d. The speed of the spacecraft if it is in a circular orbit around the Earth
e. The minimum speed of the spacecraft at point A if it is to escape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

61. A massless spring with force constant k = 400 newtons per meter is fastened at its left end to a vertical wall, as shown in Figure 1. Initially, block C (mass m_c = 4.0 kilograms) and block D (mass m_D = 2.0 kilograms) rest on a horizontal surface with block C in contact with the spring (but not compressing it) and with block *D* in contact with block C. Block C is then moved to the left, compressing the spring a distance of 0.50 meter, and held in place while block *D* remains at rest as shown in Figure 11. (Use g = 10 m/s^2.)



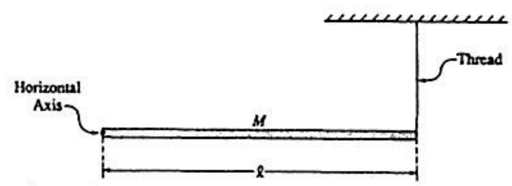
a. Determine the elastic energy stored in the compressed spring.
Block C is then released and accelerates to the right, toward block *D*. The surface is rough and the coefficient of friction between each block and the surface is μ = 0.4. The two blocks collide instantaneously, stick together, and move to the right. Remember that the spring is not attached to block C. Determine each of the following.
b. The speed v_c of block C just before it collides with block *D*
c. The speed v_f blocks C and *D* just after they collide
d. The horizontal distance the blocks move before coming to rest

62. A car of mass m, initially at rest at time t = 0, is driven to the right, as shown above, along a straight, horizontal road with the engine causing a constant force F_o to be applied. While moving, the car encounters a resistance force equal to -kv, where v is the velocity of the car and k is a positive constant.



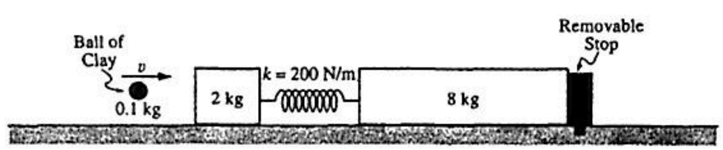
a. The dot below represents the center of mass of the car. On this figure, draw and label vectors to represent all the forces acting on the car as it moves with a velocity v to the right.
b. Determine the horizontal acceleration of the car in terms of k, v, F_o, and m.
c. Derive the equation expressing the velocity of the car as a function of time t in terms of k, F_o, and m.

63. A long, uniform rod of mass M and length *l* is supported at the left end by a horizontal axis into the page and perpendicular to the rod, as shown above. The right end is connected to the ceiling by a thin vertical thread so that the rod is horizontal. The moment of inertia of the rod about the axis at the end of the rod is $Ml^2/3$. Express the answers to all parts of this question in terms of M, *l*, and g.



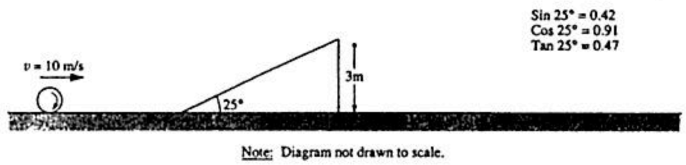
a. Determine the magnitude and direction of the force exerted on the rod by the axis.
The thread is then burned by a match. For the time immediately after the thread breaks, determine each of the following:
b. The angular acceleration of the rod about the axis
c. The translational acceleration of the center of mass of the rod
d. The force exerted on the end of the rod by the axis
The rod rotates about the axis and swings down from the horizontal position.
e. Determine the angular velocity of the rod as a function of θ, the arbitrary angle through which the rod has swung.

64. A 2-kilogram block and an 8-kilogram block are both attached to an ideal spring (for which k = 200 N/m) and both are initially at rest on a horizontal frictionless surface, as shown in the diagram above.
In an initial experiment, a 100-gram (0.1 kg) ball of clay is thrown at the 2-kilogram block. The clay is moving horizontally with speed v when it hits and sticks to the block. The 8-kilogram block is held still by a removable stop. As a result, the spring compresses a maximum distance of 0.4 meters.



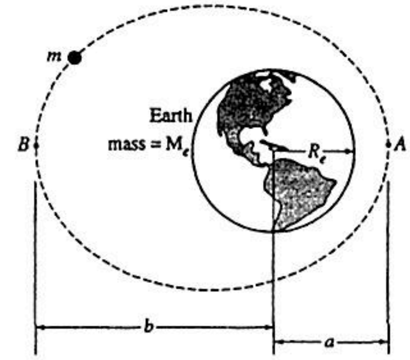
a. Calculate the energy stored in the spring at maximum compression.
b. Calculate the speed of the clay ball and 2-kilogram block immediately after the clay sticks to the block but before the spring compresses significantly.
c. Calculate the initial speed v of the clay.
In a second experiment, an identical ball of clay is thrown at another identical 2-kilogram block, but this time the stop is removed so that the 8-kilogram block is free to move.
d. State whether the maximum compression of the spring will be greater than, equal to, or less than 0.4 meter. Explain briefly.
e. State the principle or principles that can be used to calculate the velocity of the 8-kilogram block at the instant that the spring regains its original length. Write the appropriate equation(s) and show the numerical substitutions, but do <u>not</u> solve for the velocity.

65. A large sphere rolls without slipping across a horizontal surface. The sphere has a constant translational speed of 10 meters per second, a mass m of 25 kilograms, and a radius r of 0.2 meter. The moment of inertia of the sphere about its center of mass is $I = 2mr^2/5$. The sphere approaches a 25° incline of height 3 meters as shown above and rolls up the incline without slipping.



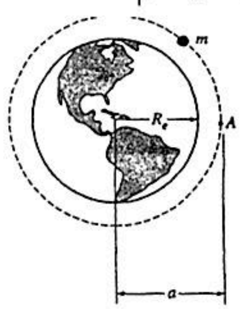
a. Calculate the total kinetic energy of the sphere as it rolls along the horizontal surface.
b. i. Calculate the magnitude of the sphere's velocity just as it leaves the top of the incline.
ii. Specify the direction of the sphere's velocity just as it leaves the top of the incline.
c. Neglecting air resistance, calculate the horizontal distance from the point where the sphere leaves the incline to the point where the sphere strikes the level surface.
d. Suppose, instead, that the sphere were to roll toward the incline as stated above, but the incline were frictionless. State whether the speed of the sphere just as it leaves the top of the incline would be less than, equal to, or greater than the speed calculated in (b). Explain briefly.

66. A satellite of mass m is in an elliptical orbit around the Earth, which has mass M_e and radius R_e. The orbit varies from closest approach of a at point A to maximum distance of b from the center of the Earth at point B. At point A, the speed of the satellite is v_o Assume that the gravitational potential energy $U_g = 0$ when masses are an infinite distance apart. Express your answers in terms of a, b, m, M_e, R_e, v_o, and G.

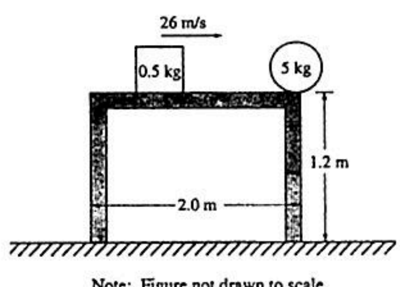


a. Write the appropriate definite integral, including limits, that can be evaluated to show that the potential energy of the satellite when it is a distance r from the center of the Earth is given by

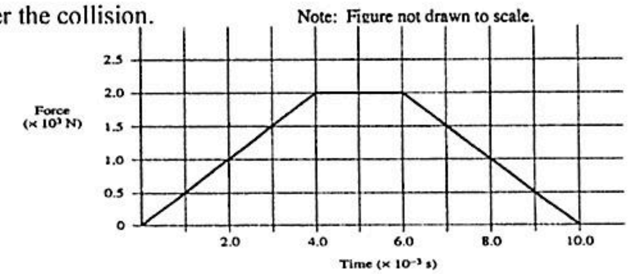
$$U_g = \frac{-Gm_e m}{r}$$



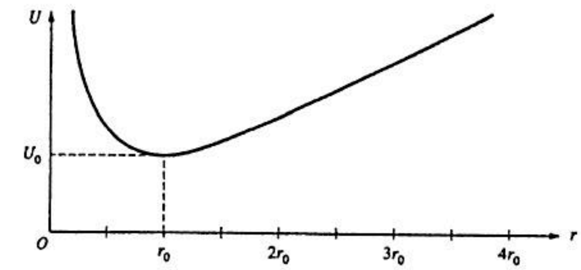
b. Determine the total energy of the satellite when it is at A.
c. What is the magnitude of the angular momentum of the satellite about the center of the Earth when it is at A ?
d. Determine the velocity of the satellite as it passes point B in its orbit.
As the satellite passes point A, a rocket engine on the satellite is fired so that its orbit is changed to a circular orbit of radius a about the center of the Earth.
e. Determine the speed of the satellite for this circular orbit.
f. Determine the work done by the rocket engine to effect this change.



67. A 5-kilogram ball initially rests at the edge of a 2-meter-long, 1.2-meter-high frictionless table, as shown above. A hard plastic cube of mass 0.5 kilogram slides across the table at a speed of 26 meters per second and strikes the ball, causing the ball to leave the table in the direction in which the cube was moving. The figure below shows a graph of the force exerted on the ball by the cube as a function of time.
a. Determine the total impulse given to the ball.
b. Determine the horizontal velocity of the ball immediately after the collision.
c. Determine the following for the cube immediately after the collision.
i. Its speed
ii. Its direction of travel (right or left), if moving
d. Determine the kinetic energy dissipated in the collision.
e. Determine the distance between the two points of impact of the objects with the floor.



68. A particle of mass m moves in a conservative force field described by the potential energy function $U(r) = a(r/b + b/r)$, where a and b are positive constants and r is the distance from the origin. The graph of U(r) has the following shape.

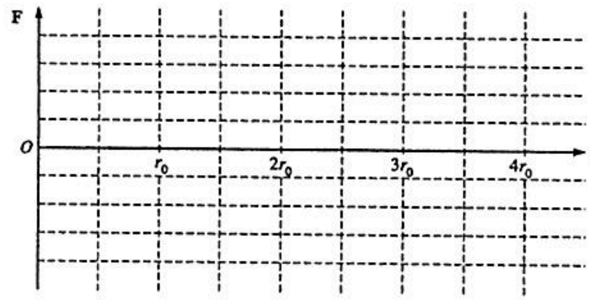


a. In terms of the constants a and b, determine the following.

i. The position r_o at which the potential energy is a minimum

ii. The minimum potential energy U_o

b. Sketch the net force on the particle as a function of on the graph below, considering a force directed away from the origin to be positive, and a force directed toward the origin to be negative.



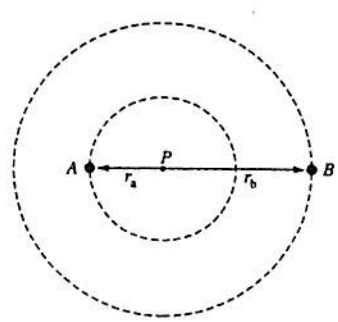
The particle is released from rest at $r = r_o/2$

c. In terms of U_o and m, determine the speed of the particle when it is at $r = r_o$.

d. Write the equation or equations that could be used to determine where, if ever, the particle will again come to rest. It is not necessary to solve for this position.

e. Briefly and qualitatively describe the motion of the particle over a long period of time.

69. Two stars, A and B. are in circular orbits of radii r_a and r_b, respectively, about their common center of mass at point P, as shown. Each star has the same period of revolution T. Determine expressions for the following three quantities in terms of r_a, r_b, T, and fundamental constants.



a. The centripetal acceleration of star A

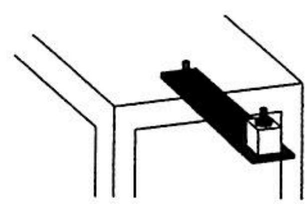
b. The mass M_b of star B

c. The mass M_a of star A

Determine expressions for the following two quantities in terms of M_a, M_b, r_a, r_b, T, and fundamental constants.

d. The moment of inertia of the two-star system about its center of mass.

e. The angular momentum of the system about the center of mass.



70. A thin, flexible metal plate attached at one end to a platform, as shown above, can be used to measure mass. When the free end of the plate is pulled down and released, it vibrates in simple harmonic motion with a period that depends on the mass attached to the plate. To calibrate the force constant, objects of known mass are attached to the plate and the plate is vibrated, obtaining the data shown below.

a. Fill in the blanks in the data table.

b. On the graph below, plot T^2 versus mass. Draw on the graph the line that is your estimate of the best straight-line fit to the data points.

c. An object whose mass is not known is vibrated on the plate, and the average time for ten vibrations is measured to be 16.1 s. From your graph, determine the mass of the object. Write your answer with a reasonable number of significant digits.

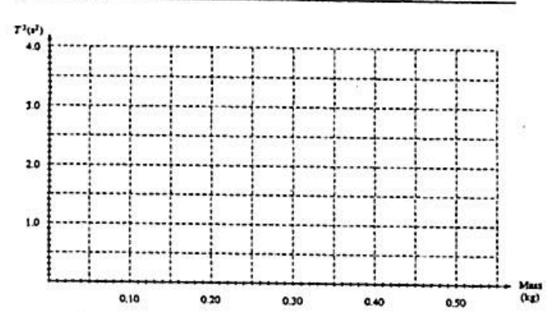
d. Explain how one could determine the force constant of the metal plate.

e. Can this device be used to measure mass aboard the space shuttle Columbia as it orbits the Earth? Explain briefly.

f. If Columbia is orbiting at 0.3×10^6 m above the Earth's surface, what is the acceleration of Columbia due to the Earth's gravity? (Radius of Earth = 6.4×10^6 m, mass of Earth = 6.0×10^{24} kg)

g. Since the answer to part (f) is not zero, briefly explain why objects aboard the orbiting Columbia seem weightless.

Mass (kg)	Average Time for Ten Vibrations (s)	Period T (s)	T^2 (s^2)
0.10	8.86		
0.20	10.6		
0.30	13.5		
0.40	14.7		
0.50	17.7		



71. A 300-kg box rests on a platform attached to a forklift, shown above. Starting from rest at at time = 0, the box is lowered with a downward acceleration of $1.5 m/s^2$

a. Determine the upward force exerted by the horizontal platform on the box as it is lowered.

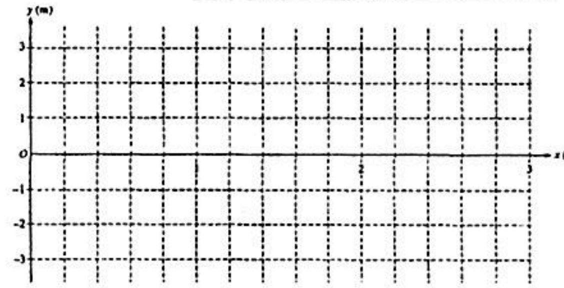
At time t = 0, the forklift also begins to move forward with an acceleration of $2 m/s^2$ while lowering the box as described above. The box does not slip or tip over.

b. Determine the frictional force on the box.

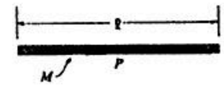
c. Given that the box does not slip, determine the minimum possible coefficient of friction between the box and the platform.

d. Determine an equation for the path of the box that expresses y as a function of x (and <u>not</u> of t), assuming that, at time t = 0, the box has a horizontal position x = 0 and a vertical position y = 2 m above the ground, with zero velocity.

e. On the axes below sketch the path taken by the box



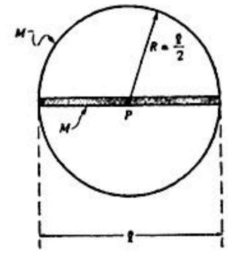
72. Consider a thin uniform rod of mass M and length l, as shown.



a. Show that the rotational inertia of the rod about an axis through its center and perpendicular to its length is $Ml^2/12$.

The rod is now glued to a thin hoop of mass M and radius $l/2$ to form a rigid assembly, as shown above. The centers of the rod and the hoop coincide at point P. The assembly is mounted on a horizontal axle through point P and perpendicular to the page.

b. What is the rotational inertia of the rod-hoop assembly about the axle?



Several turns of string are wrapped tightly around the circumference of the hoop. The system is at rest when a cat, also of mass M, grabs the free end of the string and hangs vertically from it without swinging as it unwinds, causing the rod-hoop assembly to rotate. Neglect friction and the mass of the string.

c. Determine the tension T in the string.

d. Determine the angular acceleration a of the rod-hoop assembly.

e. Determine the linear acceleration of the cat.

f. After descending a distance $H = 5l/3$, the cat lets go of the string. At that instant, what is the angular momentum of the cat about point P ?

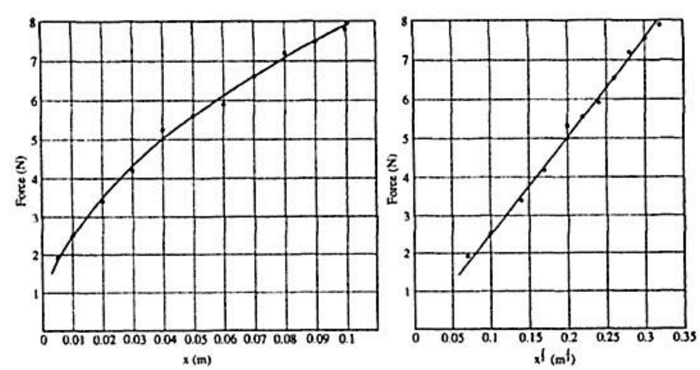
73. A nonlinear spring is compressed horizontally. The spring exerts a force that obeys the equation $F(x) = Ax^{1/2}$, where x is the distance from equilibrium that the spring is compressed and A is a constant. A physics student records data on the force exerted by the spring as it is compressed and plots the two graphs below, which include the data and the student's best-fit curves.

a. From one or both of the given graphs, determine A. Be sure to show your work and specify the units.

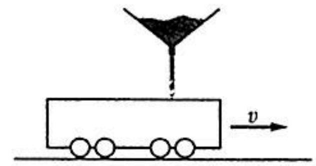
b. i. Determine an expression for the work done in compressing the spring a distance x.

ii. Explain in a few sentences how you could use one or both of the graphs to estimate a numerical answer to part (b)i for a given value of x.

c. The spring is mounted horizontally on a countertop that is 1.3 m high so that its equilibrium position is just at the edge of the countertop. The spring is compressed so that it stores 0.2 J of energy and is then used to launch a ball of mass 0.10 kg horizontally from the countertop. Neglecting friction, determine the horizontal distance d from the edge of the countertop to the point where the hall strikes the floor

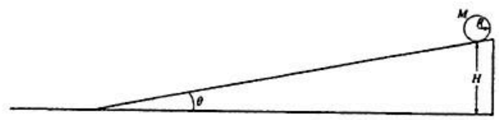


74. An open-top railroad car (initially empty and of mass M_o) rolls with negligible friction along a straight horizontal track and passes under the spout of a sand conveyor. When the car is under the conveyor, sand is dispensed from the conveyor in a narrow stream at a steady rate $\Delta M/\Delta t = C$ and falls vertically from an average height h above the floor of the railroad car. The car has initial speed v_o and sand is filling it from time $t = 0$ to $t = T$. Express your answers to the following in terms of the given quantities and g.

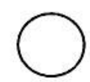


a. Determine the mass M of the car plus the sand that it catches as a function of time t for $C < t < T$.
b. Determine the speed v of the car as a function of time t for $0 < t < T$.
c. i. Determine the initial kinetic energy K_i of the empty car.
   ii. Determine the final kinetic energy K_f of the car and its load.
   iii. Is kinetic energy conserved? Explain why or why not.
d. Determine expressions for the normal force exerted on the car by the tracks at the following times.
   i. Before $t = 0$
   ii. For $0 < t < T$
   iii. After $t = T$

75. A solid cylinder with mass M, radius R, and rotational inertia $\frac{1}{2}MR^2$ rolls without slipping down the inclined plane shown above. The cylinder starts from rest at a height H. The inclined plane makes an angle θ with the horizontal. Express all solutions in terms of M, R, H, θ, and g.

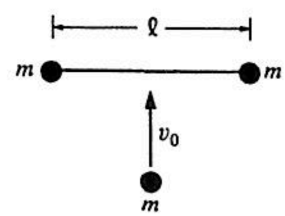


a. Determine the translational speed of the cylinder when it reaches the bottom of the inclined plane.
b. On the figure below, draw and label the forces acting on the cylinder as it rolls down the inclined plane. Your arrow should begin at the **point of application** of each force.

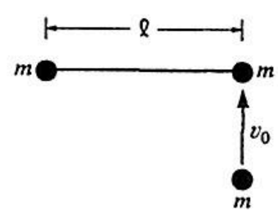


c. Show that the acceleration of the center of mass of the cylinder while it is rolling down the inclined plane is $(2/3)g \sin\theta$.
d. Determine the minimum coefficient of friction between the cylinder and the inclined plane that is required for the cylinder to roll without slipping.
e. The coefficient of friction μ is now made less than the value determined in part (d), so that the cylinder both rotates and slips.
   i. Indicate whether the translational speed of the cylinder at the bottom of the inclined plane is greater than, less than, or equal to the translational speed calculated in part (a). Justify your answer.
   ii. Indicate whether the total kinetic energy of the cylinder at the bottom of the inclined plane is greater than, less than, or equal to the total kinetic energy for the previous case of rolling without slipping. Justify your answer.

76. A space shuttle astronaut in a circular orbit around the Earth has an assembly consisting of two small dense spheres, each of mass m, whose centers are connected by a rigid rod of length l and negligible mass. The astronaut also has a device that will launch a small lump of clay of mass m at speed v_0. Express your answers in terms of m, v_0 l. and fundamental constants.

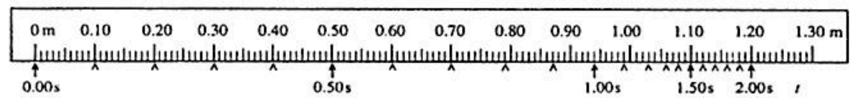


a. Initially, the assembly is "floating" freely at rest relative to the cabin, and the astronaut launches the clay lump so that it perpendicularly strikes and sticks to the midpoint of the rod, as shown above.
i. Determine the total kinetic energy of the system (assembly and clay lump) after the collision.
ii. Determine the change in kinetic energy as a result of the collision.



b. The assembly is brought to rest, the clay lump removed, and the experiment is repeated as shown above, with the clay lump striking perpendicular to the rod but this time sticking to one of the spheres of the assembly.
i. Determine the distance from the left end of the rod to the center of mass of the system (assembly and clay lump) immediately after the collision. (Assume that the radii of the spheres and clay lump are much smaller than the separation of the spheres.)
ii. On the figure above, indicate the direction of the motion of the center of mass immediately after the collision.
iii. Determine the speed of the center of mass immediately after the collision.
iv. Determine the angular speed of the system (assembly and clay lump) immediately after the collision.
v. Determine the change in kinetic energy as a result of the collision.

77. Two gliders move freely on an air track with negligible friction, as shown above. Glider A has a mass of 0.90 kg and glider B has a mass of 0.60 kg. Initially, glider A moves toward glider B, which is at rest. A spring of negligible mass is attached to the right side of glider A. Strobe photography is used to record successive positions of glider A at 0.10 s intervals over a total time of 2.00 s, during which time it collides with glider B.



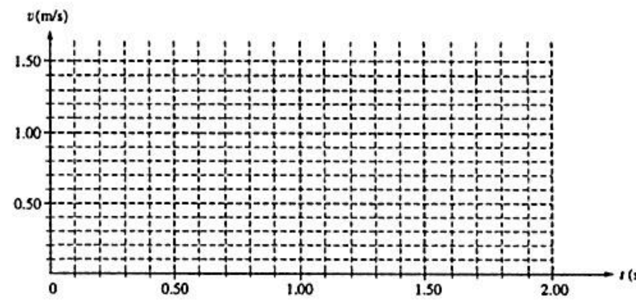
The following diagram represents the data for the motion of glider A. Positions of glider A at the end of each 0.10s interval are indicated by the symbol A against a metric ruler. The total elapsed time t after each 0.50 s is also indicated.

a. Determine the average speed of glider A for the following time intervals.

i. 0.10 s to 0.30 s

ii. 0.90 s to 1.10 s

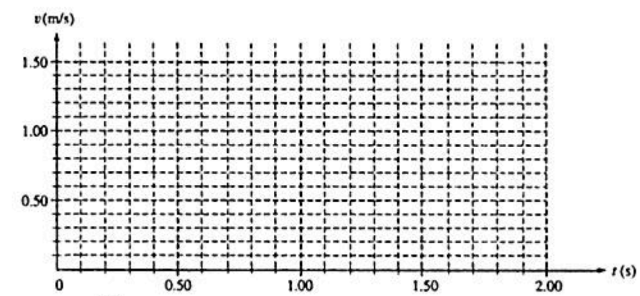
iii. 1.70 s to 1.90 s



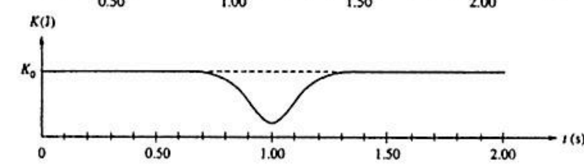
b. On the axes below, sketch a graph, consistent with the data above, of the speed of glider A as a function of time t for the 2.00 s interval.

c. i. Use the data to calculate the speed of glider B immediately after it separates from the spring.

ii. On the axes below, sketch a graph of the speed of glider B as a function of time t.

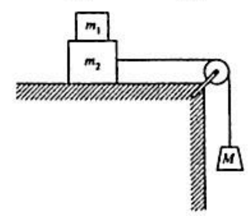


A graph of the total kinetic energy K for the two-glider system over the 2.00 s interval has the following shape. K_o is the total kinetic energy of the system at time $t = 0$.



d. i. Is the collision elastic? Justify your answer.

ii. Briefly explain why there is a minimum in the kinetic energy curve at $t = 1.00$ s.



78. Block 1 of mass m_1 is placed on block 2 of mass m_2 which is then placed on a table. A string connecting block 2 to a hanging mass M passes over a pulley attached to one end of the table, as shown above. The mass and friction of the pulley are negligible. The coefficients of friction between blocks 1 and 2 and between block 2 and the tabletop are nonzero and are given in the following table. Express your answers in terms of the masses, coefficients of friction, and g, the acceleration due to gravity.

	Coefficient Between Blocks 1 and 2	Coefficient Between Block 2 and the Tabletop
Static	μ_{s1}	μ_{s2}
Kinetic	μ_{k1}	μ_{k2}

a. Suppose that the value of M is small enough that the blocks remain at rest when released. For each of the following forces, determine the magnitude of the force and draw a vector on the block provided to indicate the direction of the force if it is nonzero.

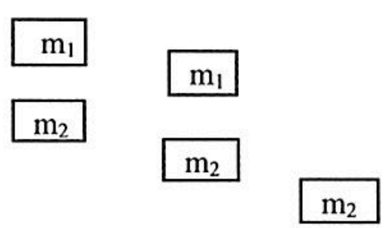
i. The normal force N_1 exerted on block 1 by block 2

ii. The friction force f_1 exerted on block 1 by block 2

iii. The force T exerted on block 2 by the string

iv. The normal force N_2 exerted on block 2 by the tabletop

v. The friction force f_2 exerted on block 2 by the tabletop



b. Determine the largest value of M for which the blocks can remain at rest.

c. Now suppose that M is large enough that the hanging block descends when the blocks are released. Assume that blocks 1 and 2 are moving as a unit (no slippage). Determine the magnitude a of their acceleration.

d. Now suppose that M is large enough that as the hanging block descends, block 1 is slipping on block 2. Determine each of the following.

i. The magnitude a_1 of the acceleration of block 1

ii. The magnitude a_2 of the acceleration of block 2