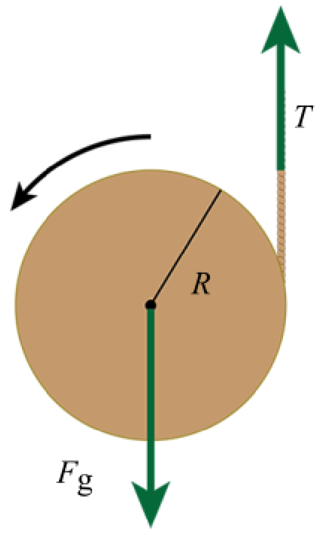
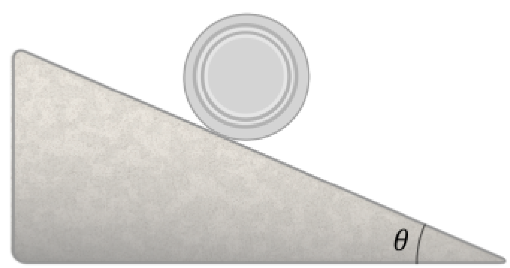
Problem 1: A cord is wrapped around a solid, uniform disk. The rope is held vertically and the disk is released. The cord unwinds without slipping as the disk falls.



Write an expression for the magnitude of the acceleration of the disk. Your answer will be in terms of g.
Expression :
a = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, **γ**, **θ**, **b**, **c**, **d**, **e**, **g**, **h**, **j**, **k**, **n**, **P**, **q**, **S**

Problem 2: A can of beans rolls without slipping down an incline that makes and angle of θ with horizontal. It is released from rest. Assume that the can is a uniform solid cylinder.

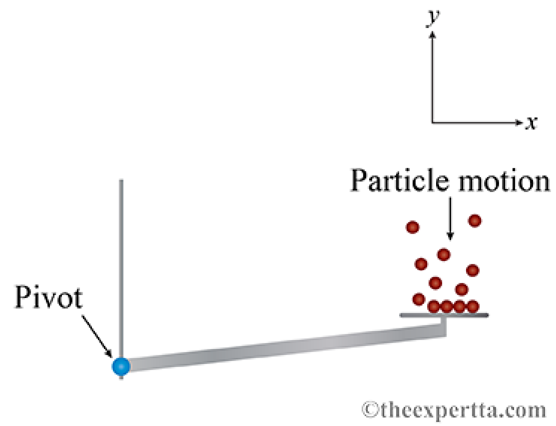


Determine an expression for the linear acceleration of the can. Your answer will be in terms of θ and g.
Expression :
a = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), **cos(φ)**, **cos(θ)**, **sin(φ)**, **sin(θ)**, **tan(θ)**, **β**, **γ**, **θ**, **d**, **g**, **h**, **n**, **P**, **Q**

Problem 3: Gallium atoms of mass $m = 1.16 \times 10^{-25}$ kg are adsorbed from a vapor to a small horizontal pan attached to a microscopic beam. The beam is attached to a post by a pivot and is inclined above the horizontal, as shown in the figure. The weight of the particles that the pan adsorbs exerts a force F on the end of the beam. The beam was designed so that it does not rotate until the torque about the pivot due to the particles reaches $\tau = 3.17 \times 10^{-20}$ N · m.

The vector extending along the beam from the pivot to the point at which the weight of the particles acts on the beam is $\vec{r} = x\,\hat{i} + y\,\hat{j}$ in the coordinate system shown in the figure.



Part (a) What is the direction of the torque that the atoms produce on the beam?
MultipleChoice :

1) Parallel to the x axis.
2) Parallel to the beam.
3) The negative z direction.
4) In the direction of $\vec{F}$.
5) Parallel to the y axis.
6) In the direction of $\vec{r}$.
7) The positive z direction.

Part (b) If $x = 2.86 \times 10^{-6}$ m, and $y = 0.33 \times 10^{-6}$ m, then what is the minimum number of gallium atoms necessary to rotate the beam?
Numeric : A numeric value is expected and not an expression.
N = ____

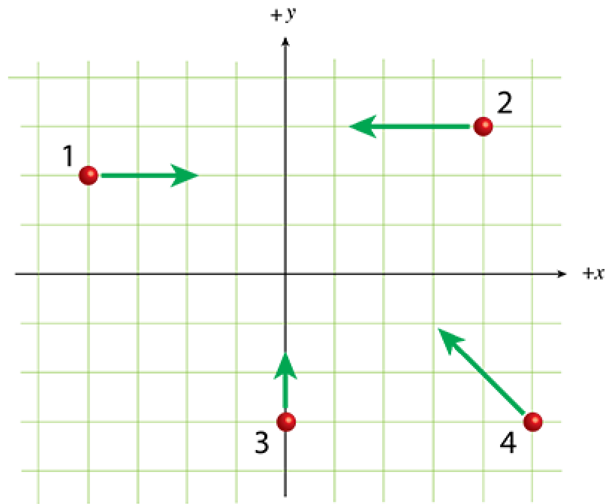
Part (c) If the beam were initially oriented at a greater angle above the horizontal, how would your answer in Part (b) change?
MultipleChoice :

1) The number of atoms necessary to rotate the beam would not change.
2) The number of atoms necessary to rotate the beam would decrease.
3) There is not enough information.
4) The number of atoms necessary to rotate the beam would increase.

Problem 4: A force $\vec{F} = (2.09\,\hat{i} + (-3.02)\,\hat{j} + 1.16\,\hat{k})$ N is applied at a point whose position is $\vec{r} = (-2.04\,\hat{i} + 3.35\,\hat{j})$ m.

What is the magnitude of the torque, in units of newton meters, generated by this force about the origin?
Numeric : A numeric value is expected and not an expression.
τ = ____ N · m

Problem 5: The diagram shows four particles (labeled 1, 2, 3, and 4) that are moving in the *x*-*y* plane. Particle 1 is at (-4 m, 2 m) and is moving in the positive *x* direction. Particle 2 is at (4 m, 3 m) and traveling in the negative *x* direction. Particle 3 is at (0 m, -3 m) and moving in the positive *y* direction. Particle 4 is at (5 m, -3 m) and its velocity makes an angle of 45 degrees with the coordinate axes.



Part (a) What is the direction of the angular momentum of particle 1 about the origin?
MultipleChoice :

1) The angular momentum is zero.
2) Positive *z*
3) Negative *z*

Part (b) What is the direction of the angular momentum of particle 2 about the origin?
MultipleChoice :

1) The angular momentum is zero.
2) Negative *z*
3) Positive *z*

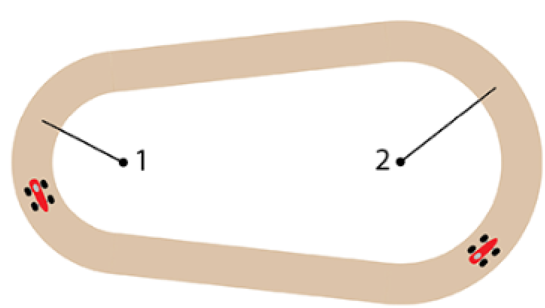
Part (c) What is the direction of the angular momentum of particle 3 about the origin?
MultipleChoice :

1) Positive *z*
2) Negative *z*
3) The angular momentum is zero.

Part (d) What is the direction of the angular momentum of particle 4 about the origin?
MultipleChoice :

1) Positive *z*
2) Negative *z*
3) The angular momentum is zero.

Problem 6: A Formula One race car drives at constant speed around a track that has two semicircular turns of radii r_1 and r_2. Let l_1 be the angular momentum of the race car about the center of turn 1 when it is driving along turn 1, and l_2 be the angular momentum of the race car about the center of turn 2 when it is driving along turn 2.



Part (a) Write an expression for the ratio $\frac{l_2}{l_1}$.

Expression :

$\frac{l_2}{l_1}$ = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, γ, θ, b, d, g, h, j, k, m, n, P, r_1, r_2, S

Part (b) If $r_1 = 32$ m and $r_2 = 88$ m what is the numerical value of $\frac{l_2}{l_1}$?

Numeric : A numeric value is expected and not an expression.

$\frac{l_2}{l_1}$ = ____

Problem 7: Suppose you start an antique car by exerting a force of *260* N on its crank for *0.16* s.

Randomized Variables

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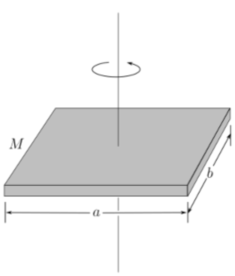
f = *260* N
t = *0.16* s
d = *0.36* m

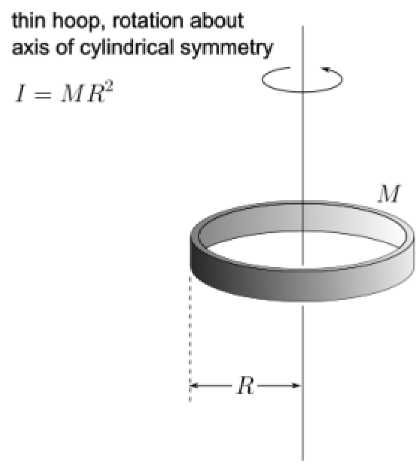
What angular momentum is given to the engine if the handle of the crank is *0.36* m from the pivot and the force is exerted to create maximum torque the entire time?

Numeric : A numeric value is expected and not an expression.

L = ____

Problem 8: A solid slab with a mass of 2.61 kg, a width of 12.2 cm, and a length of 33.3 cm is free to rotate about the z axis, which passes through its center and is perpendicular to its face. Initially at rest, a constant torque, $\vec{\tau} = (59.5 \text{ mN} \cdot \text{m})\,\hat{k}$, is applied through 7.24 s.





In lieu of the typical table as found in most textbooks, the MOIs of uniform standard objects may be obtained by using the left and right arrows to step through the image carousel to the right.

Part (a) What is the magnitude, in millijoule seconds, of the final angular momentum of the slab?

Numeric : A numeric value is expected and not an expression.

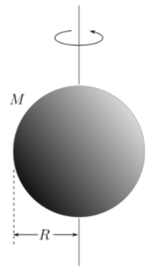
L_f = ____ mJ · s

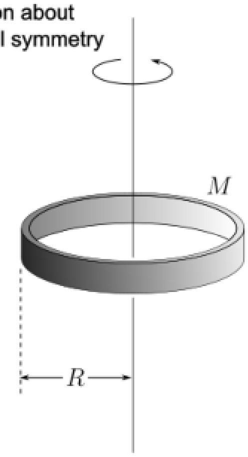
Part (b) What is the final angular velocity, in revolutions per minute, after the application of the torque?

Numeric : A numeric value is expected and not an expression.

ω_f = ____ rpm

Problem 9: A solid sphere with a mass of 2.57 kg and a radius of 32.7 cm is free to rotate about the z axis, which passes through its center. Initially at rest, a constant torque, $\vec{\tau} = \left(24.5 \text{ mN} \cdot \text{m}\right) \hat{k}$, is applied through 5.79 s.



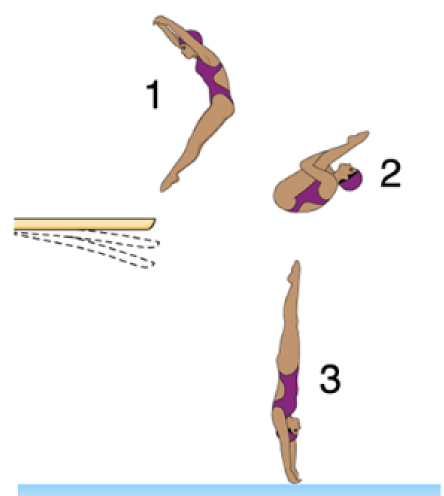


In lieu of the typical table as found in most textbooks, the MOIs of uniform standard objects may be obtained by using the left and right arrows to step through the image carousel to the right.

Part (a) What is the magnitude, in millijoule seconds, of the final angular momentum of the solid sphere?
Numeric : A numeric value is expected and not an expression.
L_f = ____ mJ · s

Part (b) What is the final angular velocity, in revolutions per minute, after the application of the torque?
Numeric : A numeric value is expected and not an expression.
ω_f = ____ rpm

Problem 10: A diver does a backflip off a 3-meter board, as shown in the diagram. Assume the diver's angular momentum is conserved as she moves from position 1 to 2 to 3. At position 1 she is beginning to tuck her body, at position 2 she is in a full tuck, and just before entering the water at position 3 she is fully extended.



Part (a) Drag and drop the images of the diver to the space below and order them from her smallest to largest moment of inertia. .
DragNDrop :
= ____

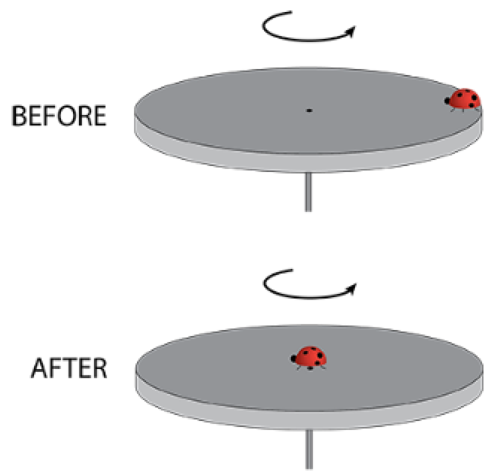
Part (b) Drag and drop the images of the diver to the space below and order them from her smallest to largest angular speed.
DragNDrop :
= ____

Problem 11: Consider a bike wheel that is hanging from a rope tied to one end of its axle (see figure).

If you get the bike wheel spinning quickly about its axis and let it go, what direction will it move?
MultipleChoice :

1) Downwards
2) Upwards
3) Around the vertical axis that coincides with the rope.
4) Horizontally, with its axis coinciding with the rope.
5) It will not move at all

Problem 12: A ladybug of mass m is at the edge of a horizontal disk of mass M and radius R that rotates freely about an axis through its center with an angular speed of ω_i. Starting at the edge of the disk, the ladybug walks towards its center.



Part (a) Write an expression for the angular speed ω_f of the disk when the ladybug is at the center. Your answer will be in terms of M, m, and ω_i.
Expression :
ω_f = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, γ, ω_i, θ, b, d, g, h, j, k, m, M, n, P, S

Part (b) Write an expression for the change (final minus initial) in kinetic energy of the system as the ladybug crawls to the center of the disk. Your answer will be in terms of R, M, m, and ω_i.
Expression :
ΔK = ____

Select from the variables below to write your expression. Note that all variables may not be required.
β, γ, ω_i, θ, g, h, j, k, m, M, n, P, Q, R, S

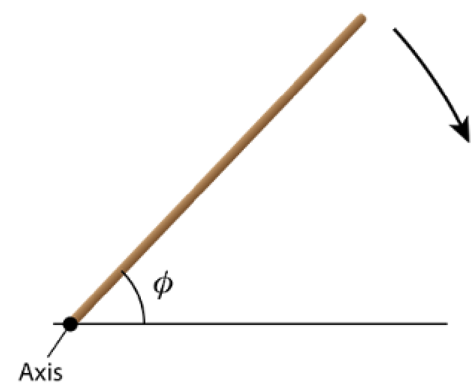
Problem 13: The Earth spins on its axis and also orbits around the Sun. For this problem use the following constants.

Mass of the Earth: 5.97×10^{24} kg (assume a uniform mass distribution)
Radius of the Earth: 6371 km
Distance of Earth from Sun: 149,600,000 km

Part (a) Calculate the rotational kinetic energy of the Earth due to rotation about its axis, in joules.
Numeric : A numeric value is expected and not an expression.
$K_{r,R}$ = ____

Part (b) What is the rotational kinetic energy of the Earth due to its orbit around the Sun, in joules?
Numeric : A numeric value is expected and not an expression.
$K_{r,O}$ = ____

Problem 14: A uniform rod with length L is free to rotate about an axis at ground level. The rod makes an angle ϕ with horizontal and is released from rest.

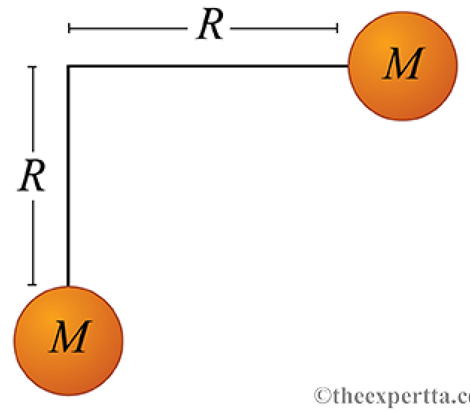


Part (a) Write an expression for the angular speed of the rod just before it strikes the ground.
Expression :
ω = ____

Select from the variables below to write your expression. Note that all variables may not be required.
cos(α), **cos(φ)**, **cos(θ)**, **sin(α)**, **sin(φ)**, **sin(θ)**, **β**, **γ**, **θ**, **d**, **g**, **L**, **m**, **n**, **q**

Part (b) If the rod has a length of 2.8 m and is dropped from an angle of 31° above the horizontal, what is the linear speed of the tip of the rod, in meters per second, just before the rod strikes the ground?
Numeric : A numeric value is expected and not an expression.
v_t = ____ m/s

Problem 15: Consider two equal masses M attached to the ends of massless rods, of length R, as shown in the figure. Treat the two masses as point masses, each located at a distance R from the point where the rods touch.

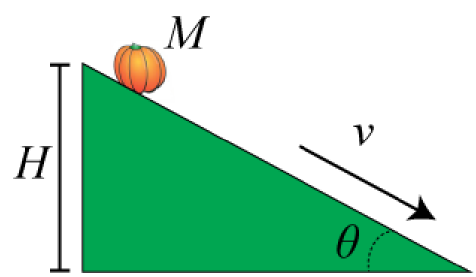


What is the moment of inertia of this system, about an axis perpendicular to the page and passing through the point where the rods touch?

MultipleChoice :

1) 1/4 MR^2
2) None of these are correct - the answer is much more complicated than any of these.
3) MR^2
4) 1/2 MR^2
5) $2MR^2$

Problem 16: You have a pumpkin of mass M and radius R. The pumpkin has the shape of a sphere, but it is not uniform inside so you do not know its moment of inertia. In order to determine the moment of inertia, you decide to roll the pumpkin down an incline that makes an angle θ with the horizontal. The pumpkin starts from rest and rolls without slipping. When it has descended a vertical height H, it has acquired a speed of $v = \sqrt{5gH/4}$.



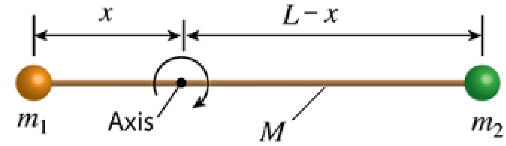
Find the moment of inertia I of the pumpkin in terms of M and R.

SchematicChoice :

$I = -\frac{8}{5}MR^2$ $\quad$ $I = -\frac{13}{5}MR^2$ $\quad$ $I = -\frac{3}{5}MR^2$

$I = \frac{8}{5}MR^2$ $\quad$ $I = \frac{3}{5}MR^2$ $\quad$ $I = \frac{13}{5}MR^2$

Problem 17: Two small spheres, with masses m_1 and m_2 are attached to the ends of a rod of mass M and length L. The system rotates about an axis that is a distance x from the sphere with mass m_1 as shown in the diagram. The system is initially at rest, but then a constant torque is applied until the angular speed of the system attains a specified value.



Determine an expression for x so that the work done by the applied torque to achieve the specified angular speed has its smallest possible value. Treat the spheres as point masses. Your answer will be in terms of m_1, m_2, M, and L.

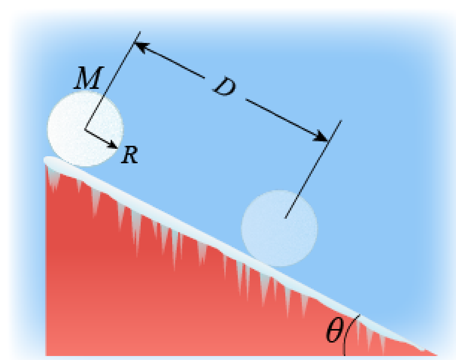
Expression :

x = ____

Select from the variables below to write your expression. Note that all variables may not be required.

β, γ, θ, d, g, h, j, k, L, M, m_1, m_2, n, P, q

Problem 18: A spherical snowball of mass M and radius R starts from rest and rolls without slipping down a roof that makes an angle θ with the horizontal.



What is the angular speed, ω, of the snowball after it has traveled a distance D down the sloped roof?

SchematicChoice :

$$\omega = \sqrt{\frac{4gD\sin\theta}{3R^2}}$$

$$\omega = \sqrt{\frac{2gD\sin\theta}{R^2}}$$

$$\omega = \sqrt{\frac{10gD\sin\theta}{7R^2}}$$

$$\omega = \sqrt{\frac{5gD\sin\theta}{R^2}}$$