Chapter 9 [Edit]

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Chapter 9

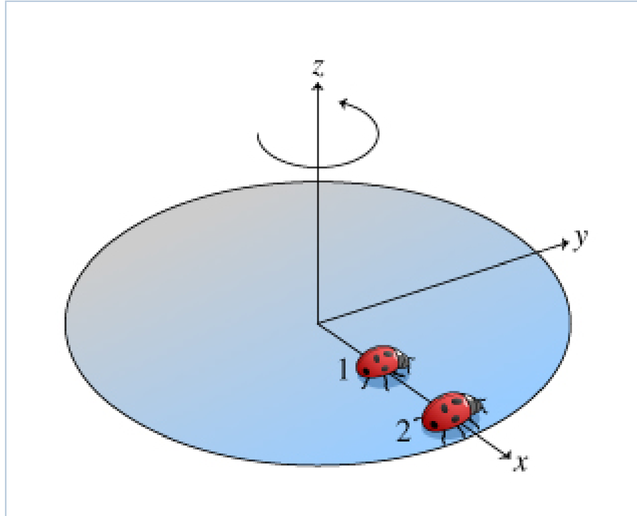
Due: 11:59pm on Sunday, October 30, 2016

To understand how points are awarded, read the Grading Policy for this assignment.

Ladybugs on a Rotating Disk

Description: Several conceptual questions about the kinematics of two ladybugs sitting at different radii on a rotating disk. Find the ratio of the linear and angular velocities, direction of acceleration, etc.

Two ladybugs sit on a rotating disk, as shown in the figure (the ladybugs are at rest with respect to the surface of the disk and do not slip). Ladybug 1 is halfway between ladybug 2 and the axis of rotation.



Part A

What is the angular speed of ladybug 1?

ANSWER:

- ○ one-half the angular speed of ladybug 2
- ◉ the same as the angular speed of ladybug 2
- ○ twice the angular speed of ladybug 2
- ○ one-quarter the angular speed of ladybug 2

Part B

What is the ratio of the linear speed of ladybug 2 to that of ladybug 1?

Answer numerically.

Hint 1. Relation between linear and angular speeds

The relation between the linear speed v and angular speed ω of an object is given by

$$v = \omega r,$$

where r is the distance between the object and the axis of rotation.

ANSWER:

2

Part C

What is the ratio of the magnitude of the radial acceleration of ladybug 2 to that of ladybug 1?

Answer numerically.

Hint 1. Radial (centripetal) acceleration of an object moving on a circle

The magnitude of the radial (centripetal) acceleration of an object moving on a circle is called the centripetal acceleration. It is given by

$$a_c = \omega^2 r = \frac{v_{\rm t}^2}{r},$$

where ω is the angular velocity of the object, $v_{\rm t}$ is its tangential velocity, and r is the distance from the axis of rotation.

ANSWER:

$\frac{a_2}{a_1}$ = 2

Although the trajectory of ladybug 2 has twice the radius as that of ladybug 1, ladybug 2 also has twice the linear velocity of ladybug 1. Thus, according to the formula $a_c = v^2/r$, where a_c is centripetal acceleration, ladybug 2 has twice the centripetal acceleration of ladybug 1.

Part D

What is the direction of the vector representing the angular velocity of ladybug 2? See the figure for the directions of the coordinate axes.

Hint 1. Direction of the angular velocity vector

The direction of the angular velocity vector is given by the right-hand rule. Curl the fingers of your right hand along the direction of rotation, and your thumb will point along the direction of the angular velocity vector.

ANSWER:

- ○ $+x$
- ○ $-x$
- ○ $+y$
- ○ $-y$
- ● $+z$
- ○ $-z$

Part E

Now assume that at the moment pictured in the figure, the disk is rotating but slowing down. Each ladybug remains "stuck" in its position on the disk. What is the direction of the *tangential* component of the acceleration (i.e., acceleration tangent to the trajectory) of ladybug 2?

ANSWER:

- ○ $+x$
- ○ $-x$
- ○ $+y$
- ◉ $-y$
- ○ $+z$
- ○ $-z$

Exercise 9.1

Description: (a) What angle in radians is subtended by an arc of L_1 in length on the circumference of a circle of radius r_1? (b) What is this angle in degrees? (c) An arc of length L_2 on the circumference of a circle subtends an angle of theta_1. What is...

Part A

What angle in radians is subtended by an arc of 1.54 m in length on the circumference of a circle of radius 2.44 m ?

ANSWER:

$\theta = \frac{L_1}{r_1} = 0.631 \quad \mathrm{rad}$

Part B

What is this angle in degrees?

ANSWER:

$\theta = \frac{L_1}{r_1}\frac{180}{\pi} = 36.2 \quad ^\circ$

Part C

An arc of length 14.7 cm on the circumference of a circle subtends an angle of 130 $^\circ$. What is the radius of the circle?

ANSWER:

$r = \frac{L_2}{\theta_1} = 6.48 \quad \mathrm{cm}$

Part D

The angle between two radii of a circle with radius 1.48 m is 0.660 rad . What length of arc is intercepted on the circumference of the circle by the two radii?

ANSWER:

L = $r_2\theta_2$ = 0.977 m

Exercise 9.6

Description: At t=0 the current to a dc electric motor is reversed, resulting in an angular displacement of the motor shaft given by theta (t) = (A)t-(B)t^2-(C)t^3. (a) At what time is the angular velocity of the motor shaft zero? (b)...

At $t = 0$ the current to a dc electric motor is reversed, resulting in an angular displacement of the motor shaft given by $\theta(t) = ($ 244 $\mathrm{rad/s}\ )t - ($ 21.0 $\mathrm{rad/s^2}\ )t^2 - ($ 1.50 $\mathrm{rad/s^3}\ )t^3$.

Part A

At what time is the angular velocity of the motor shaft zero?

ANSWER:

t = $\dfrac{-B+\sqrt{B^2+3AC}}{3C}$ = 4.05 s

Part B

Calculate the angular acceleration at the instant that the motor shaft has zero angular velocity.

ANSWER:

α = $-2B - \dfrac{6C\left(-B+\sqrt{B^2+3AC}\right)}{3C}$ = -78.5 $\mathrm{rad/s^2}$

Part C

How many revolutions does the motor shaft turn through between the time when the current is reversed and the instant when the angular velocity is zero?

ANSWER:

N = $\dfrac{\frac{A\left(-B+\sqrt{B^2+3AC}\right)}{3C} - B\left(\frac{-B+\sqrt{B^2+3AC}}{3C}\right)^2 - C\left(\frac{-B+\sqrt{B^2+3AC}}{3C}\right)^3}{2\pi}$ = 86.6 rev

Part D

How fast was the motor shaft rotating at $t = 0$, when the current was reversed?

ANSWER:

ω = A = 244 $\mathrm{rad/s}$

Part E

Calculate the average angular velocity for the time period from $t = 0$ to the time calculated in part A.

ANSWER:

$\omega_{\rm av}$ = $A - \frac{B\left(-B+\sqrt{B^2+3AC}\right)}{3C} - C\left(\frac{-B+\sqrt{B^2+3AC}}{3C}\right)^2$ = 134 $\mathrm{rad/s}$

Exercise 9.9

Description: A bicycle wheel has an initial angular velocity of w. (a) If its angular acceleration is constant and equal to 0.200 rad/s^2, what is its angular velocity at t = 2.50 s? (b) Through what angle has the wheel turned between t = 0 and t = ...

A bicycle wheel has an initial angular velocity of 0.500 $\mathrm{rad/s}$.

Part A

If its angular acceleration is constant and equal to 0.200 $\mathrm{rad/s^2}$, what is its angular velocity at t = 2.50 s?

ANSWER:

ω = $w + 0.2 \cdot 2.5$ = 1.00 $\frac{\mathrm{rad}}{\mathrm{s}}$

Part B

Through what angle has the wheel turned between t = 0 and t = 2.50 s?

Express your answer with the appropriate units.

ANSWER:

$\Delta\theta$ = $w \cdot 2.5 + 0.5 \cdot 0.2 \cdot 2.5^2$ = 1.88 rad

Exercise 9.16

Description: At t=0 a grinding wheel has an angular velocity of omega. It has a constant angular acceleration of a until a circuit breaker trips at time t. From then on, it turns through an angle theta as it coasts to a stop at constant angular acceleration. (a)...

At $t = 0$ a grinding wheel has an angular velocity of 27.0 $\mathrm{rad/s}$. It has a constant angular acceleration of 35.0 $\mathrm{rad/s^2}$ until a circuit breaker trips at time t = 1.60 s . From then on, it turns through an angle 440 rad as it coasts to a stop at constant angular acceleration.

Part A

Through what total angle did the wheel turn between $t = 0$ and the time it stopped?

ANSWER:

θ = $\theta + \omega t + \frac{1}{2}at^2$ = 528 rad

Part B

At what time did it stop?

ANSWER:

t = $\frac{2\theta}{\omega + at} + t$ = 12.2 s

Part C

What was its acceleration as it slowed down?

ANSWER:

α = $\frac{\frac{-(\omega+at)^2}{2}}{\theta}$ = -7.83 $\mathrm{rad/s^2}$

Exercise 9.26

Description: At a time t, a point on the rim of a wheel with a radius of r has a tangential speed of v as the wheel slows down with a tangential acceleration of constant magnitude a. (a) Calculate the wheel's constant angular acceleration. (b) Calculate the...

At a time t = 2.60 s , a point on the rim of a wheel with a radius of 0.180 m has a tangential speed of 47.0 $\mathrm{m/s}$ as the wheel slows down with a tangential acceleration of constant magnitude 10.2 $\mathrm{m/s^2}$.

Part A

Calculate the wheel's constant angular acceleration.

ANSWER:

α = $\frac{-a}{r}$ = -56.7 $\mathrm{rad/s^2}$

Part B

Calculate the angular velocity at t = 2.60 s .

ANSWER:

ω = $\frac{v}{r}$ = 261 $\mathrm{rad/s}$

Part C

Calculate the angular velocity at $t = 0$.

ANSWER:

ω_0 = $\frac{v+at}{r}$ = 408 $\mathrm{rad/s}$

Part D

Through what angle did the wheel turn between $t = 0$ and t = 2.60 s ?

ANSWER:

θ = $\frac{\frac{v+v+at}{r}}{2}t$ = 870 rad

Part E

Prior to the wheel coming to rest, at what time will the radial acceleration at a point on the rim equal g = 9.81 $\mathrm{m/s^2}$?

ANSWER:

t = $\frac{v-\sqrt{gr}}{a}+t$ = 7.08 s

Exercise 9.29

Description: Calculate the moment of inertia of each of the following uniform objects about the axes indicated. Consult Table Moments of Inertia of Various Bodies in the Textbook as needed. (a) A thin mrod-kg rod of length lrod, about an axis perpendicular to it...

Calculate the moment of inertia of each of the following uniform objects about the axes indicated. Consult Table **Moments of Inertia of Various Bodies** in the Textbook as needed.

Part A

A thin 3.00-kg rod of length 65.0 cm , about an axis perpendicular to it and passing through one end.

ANSWER:

$I = \frac{1}{3} mrodlrod^2$ = 0.423 $\mathrm{kg \cdot m^2}$

Part B

A thin 3.00-kg rod of length 65.0 cm , about an axis perpendicular to it and passing through its center.

ANSWER:

$I = \frac{1}{12} mrodlrod^2$ = 0.106 $\mathrm{kg \cdot m^2}$

Part C

A thin 3.00-kg rod of length 65.0 cm , about an axis parallel to the rod and passing through it.

ANSWER:

$I =$ 0 $\mathrm{kg \cdot m^2}$

Part D

A 4.50-kg sphere 27.0 cm in diameter, about an axis through its center, if the sphere is solid.

ANSWER:

$I = \frac{2}{5} msph \left(\frac{dsph}{2}\right)^2$ = 3.28×10^{-2} $\mathrm{kg \cdot m^2}$

Part E

A 4.50-kg sphere 27.0 cm in diameter, about an axis through its center, if the sphere is a thin-walled hollow shell.

ANSWER:

$I = \frac{2}{3} msph \left(\frac{dsph}{2}\right)^2$ = 5.47×10^{-2} $\mathrm{kg \cdot m^2}$

Part F

An 8.00-kg cylinder, of length 12.0 cm and diameter 10.0 cm , about the central axis of the cylinder, if the cylinder is thin-walled and hollow.

ANSWER:

$$I = mcyl\left(\frac{dcyl}{2}\right)^2 = 2.00\times10^{-2} \quad \mathrm{kg\cdot m^2}$$

Part G

An 8.00-kg cylinder, of length 12.0 cm and diameter 10.0 cm , about the central axis of the cylinder, if the cylinder is solid.

ANSWER:

$$I = \frac{1}{2}mcyl\left(\frac{dcyl}{2}\right)^2 = 1.00\times10^{-2} \quad \mathrm{kg\cdot m^2}$$

Exercise 9.31

Description: A uniform bar has two small balls glued to its ends. The bar is 2.00 m long and has mass m, while the balls each have mass 0.300 kg and can be treated as point masses. (a) Find the moment of inertia of this combination about an axis...

A uniform bar has two small balls glued to its ends. The bar is 2.00 m long and has mass 7.00 kg , while the balls each have mass 0.300 kg and can be treated as point masses.

Part A

Find the moment of inertia of this combination about an axis perpendicular to the bar through its center.

Express your answer with the appropriate units.

ANSWER:

$$I = \frac{1}{12}m\cdot2^2 + 2\cdot0.3\cdot1^2 = 2.93\mathrm{kg\cdot m^2}$$

Part B

Find the moment of inertia of this combination about an axis perpendicular to the bar through one of the balls.

Express your answer with the appropriate units.

ANSWER:

$$I = \frac{1}{3}m\cdot2^2 + 0.3\cdot2^2 = 10.5\mathrm{kg\cdot m^2}$$

Part C

Find the moment of inertia of this combination about an axis parallel to the bar through both balls.

Express your answer with the appropriate units.

ANSWER:

I = $0 \mathrm{kg \cdot m^2}$

Part D

Find the moment of inertia of this combination about an axis parallel to the bar and 0.500 m from it.

Express your answer with the appropriate units.

ANSWER:

I = $(m + 2 \cdot 0.3) \cdot 0.5^2$ = 1.90$\mathrm{kg \cdot m^2}$

Exercise 9.41

Description: Energy is to be stored in a flywheel in the shape of a uniform solid disk with a radius of R m and a mass of m. To prevent structural failure of the flywheel, the maximum allowed radial acceleration of a point on its rim is a. (a) What is the...

Energy is to be stored in a flywheel in the shape of a uniform solid disk with a radius of R = 1.22 m and a mass of 75.0 kg . To prevent structural failure of the flywheel, the maximum allowed radial acceleration of a point on its rim is 3540 $\mathrm{m/s^2}$.

Part A

What is the maximum kinetic energy that can be stored in the flywheel?

ANSWER:

K = $\frac{\frac{1}{2} \cdot 1}{2} mRa$ = 8.10×10^4 J

Exercise 9.51

Description: A thin, rectangular sheet of metal has mass M and sides of length a and b. (a) Use the parallel-axis theorem to calculate the moment of inertia of the sheet for an axis that is perpendicular to the plane of the sheet and that passes through one...

A thin, rectangular sheet of metal has mass M and sides of length a and b.

Part A

Use the parallel-axis theorem to calculate the moment of inertia of the sheet for an axis that is perpendicular to the plane of the sheet and that passes through one corner of the sheet.

Express your answer in terms of given quantities.

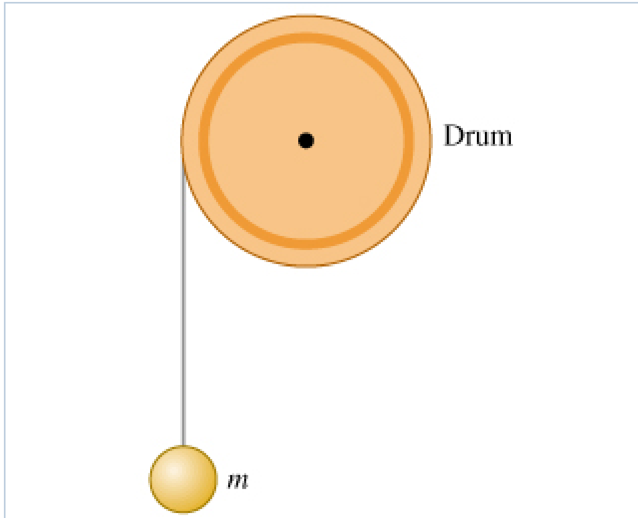
ANSWER:

$I = \frac{1}{3}M\left(a^2+b^2\right)$

Problem 9.62

Description: Engineers are designing a system by which a falling mass m imparts kinetic energy to a rotating uniform drum to which it is attached by thin, very light wire wrapped around the rim of the drum (the figure). There is no appreciable friction in the...

Engineers are designing a system by which a falling mass m imparts kinetic energy to a rotating uniform drum to which it is attached by thin, very light wire wrapped around the rim of the drum (the figure). There is no appreciable friction in the axle of the drum, and everything starts from rest. This system is being tested on earth, but it is to be used on Mars, where the acceleration due to gravity is 3.71 $\mathrm{m/s^2}$. In the earth tests, when m is set to 17.0 kg and allowed to fall through 4.50 m , it gives 300.0 J of kinetic energy to the drum.



Part A

If the system is operated on Mars, through what distance would the 17.0-kg mass have to fall to give the same amount of kinetic energy to the drum?

ANSWER:

$h = \frac{g}{3.71}s$ = 11.9 m

Part B

How fast would the 17.0-kg mass be moving on Mars just as the drum gained 300.0 J of kinetic energy?

ANSWER:

$v = \sqrt{2gs-\frac{2K}{m}}$ = 7.27 $\mathrm{m/s}$

Problem 9.64

Description: The motor of a table saw is rotating at 3450 rev/min. A pulley attached to the motor shaft drives a second pulley of half the diameter by means of a V-belt. A circular saw blade of diameter 0.208 m is mounted on the same rotating shaft as the second...

The motor of a table saw is rotating at 3450 $\mathrm{rev/min}$. A pulley attached to the motor shaft drives a second pulley of half the diameter by means of a V-belt. A circular saw blade of diameter 0.208 m is mounted on the same rotating shaft as the second pulley.

Part A

The operator is careless and the blade catches and throws back a small piece of wood. This piece of wood moves with linear speed equal to the tangential speed of the rim of the blade. What is this speed?

ANSWER:

v = 75.1 $\mathrm{m/s}$

Part B

Calculate the radial acceleration of points on the outer edge of the blade to see why sawdust doesn't stick to its teeth.

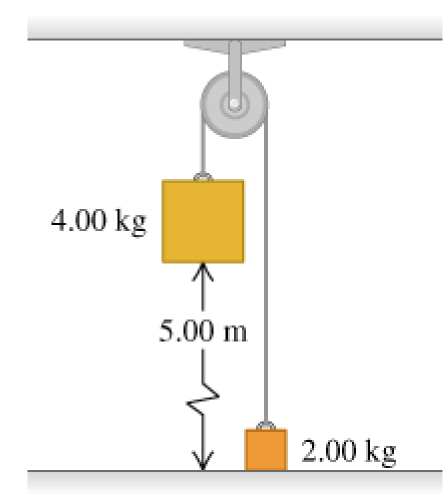
ANSWER:

a_r = 5.43×10^4 $\mathrm{m/s^2}$

Problem 9.76

Description: The pulley in has radius 0.160 m and a moment of inertia 0.380 (kg) * m^2. The rope does not slip on the pulley rim. (a) Use energy methods to calculate the speed of the 4.00-kg block just before it strikes the floor.

The pulley in has radius 0.160 m and a moment of inertia 0.380 $\mathrm{kg\cdot m^2}$. The rope does not slip on the pulley rim.



Part A

Use energy methods to calculate the speed of the 4.00-kg block just before it strikes the floor.

Express your answer with the appropriate units.

ANSWER:

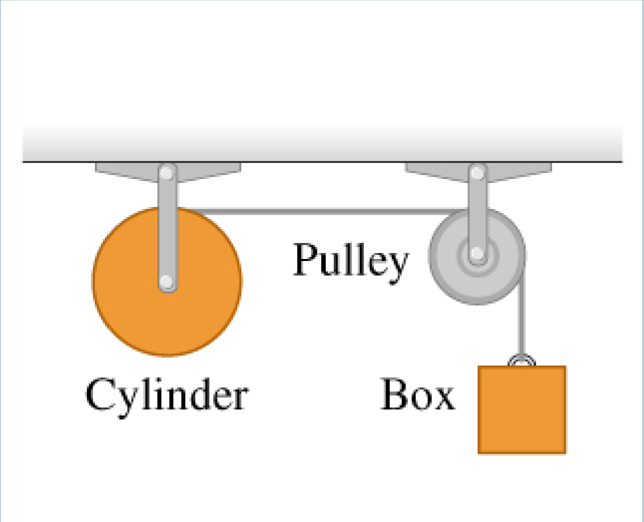
v = 3.07 $\frac{\mathrm{m}}{\mathrm{s}}$

Also accepted: 3.07 $\frac{\mathrm{m}}{\mathrm{s}}$, 3.07 $\frac{\mathrm{m}}{\mathrm{s}}$

Problem 9.80

Description: In the following figure , the cylinder and pulley turn without friction about stationary horizontal axles that pass through their centers. A light rope is wrapped around the cylinder, passes over the pulley, and has a 3.00-kg box suspended from its...

In the following figure , the cylinder and pulley turn without friction about stationary horizontal axles that pass through their centers. A light rope is wrapped around the cylinder, passes over the pulley, and has a 3.00-kg box suspended from its free end. There is no slipping between the rope and the pulley surface. The uniform cylinder has mass 5.00 kg and radius 40.0 cm. The pulley is a uniform disk with mass 2.00 kg and radius 20.0 cm. The box is released from rest and descends as the rope unwraps from the cylinder.



Part A

Find the speed of the box when it has fallen 2.50 m.

ANSWER:

v = 4.76 $\mathrm{m/s}$