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Chapter 11

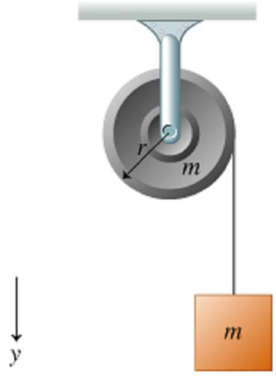
Due: 12:00am on Saturday, July 3, 2010

Note: You will receive no credit for late submissions. To learn more, read your instructor's Grading Policy

Acceleration of a Pulley

Description: A block of mass m hangs from a string wrapped around a cylinder that also has mass m. Find the angular acceleration of the cylinder. An application of Newton's second law in its linear and angular forms.

A string is wrapped around a uniform solid cylinder of radius r, as shown in the figure . The cylinder can rotate freely about its axis. The loose end of the string is attached to a block. The block and cylinder each have mass m. Note that the positive y direction is downward and counterclockwise torques are positive.



Part A

Find the magnitude α of the angular acceleration of the cylinder as the block descends.

Hint A.1 How to approach the problem

1. The block does not rotate. To analyze its motion, you should use Newton's second law in its linear form: $F = ma$.
2. The pulley rotates. To analyze its motion, you should use Newton's second law in its angular form: $\tau = I\alpha$.
3. Using the geometry of the situation, you need to find the relationship between a and α.
4. Finally, solve the system of three equations to obtain an expression for α.

Hint A.2 Find the net force on the block

The block has two forces acting on it: the tension of the string and its own weight. What is the net force F acting on the block? Use the coordinate system shown in the figure.

Express your answer in terms of m, g (the magnitude of the acceleration due to gravity), and T (the tension in the string).

ANSWER: $F = ma =$ $mg - T$

Hint A.3 Find the net torque on the pulley

The tension T in the string produces a torque that acts on the pulley. What is the torque?

Hint A.3.1 Formula for torque

Recall that $\tau = rF\sin(\phi)$, where F is the force causing the torque, r is the distance from the pivot to the point at which the force acts, and ϕ is the angle between the position vector of the point mentioned above and the force vector.

Express your answer in terms of the cylinder's radius r and the tension T in the string.

ANSWER: $I\alpha =$ $-Tr$

The moment of inertia of a uniform cylinder about its axis is equal to $\frac{1}{2}mr^2$. Substituting this into the above equation gives

$$\frac{1}{2}mr\alpha = -T.$$

Hint A.4 Relate linear and angular acceleration

The string does not stretch. Therefore, there is a geometric constraint between the linear acceleration a and the angular acceleration α. What is the cylinder's angular acceleration α in terms of the linear acceleration a of the block?

Express your answer in terms of a and r. Be careful with your signs.

ANSWER: $\alpha = \frac{-a}{r}$

From this equation, $a = -\alpha r$. Substitute for a in the force equation for the block.

Hint A.5 Putting it together

Solve the system of equations to eliminate T and obtain an expression for α.

Express your answer in terms of the cylinder's radius r and the magnitude of the acceleration due to gravity g.

ANSWER: $\alpha = \frac{\frac{2}{3}g}{r}$

Note that the magnitude of the linear acceleration of the block is $\frac{2}{3}g$, which does not depend on the value of r.

Balancing Torques Ranking Task

Description: Rank the tension in a torque-balancing support cable in various configurations. (ranking task)

A sign is to be hung from the end of a thin pole, and the pole supported by a single cable. Your design firm brainstorms the six scenarios shown below. In scenarios A, B, and D, the cable is attached halfway between the midpoint and end of the pole. In C, the cable is attached to the mid-point of the pole. In E and F, the cable is attached to the end of the pole.

Part A

Rank the design scenarios (A through F) on the basis of the tension in the supporting cable.

Hint A.1 How to approach the problem

In all cases, the pole and sign are held in equilibrium by the torque supplied by the cable. Therefore, by setting the torque due to the cable equal to the torque due to the sign and the pole, you can determine the relative tension in the cable. Note that the pole and sign are the same in each case, so the torque due to them is the same for each case.

Hint A.2 The mathematical relationship

The torque due to the cable is given by

$$\tau = rF\sin\theta,$$

where r is the distance from the hinge to the force and θ is the angle of the force relative to the pole. Since the pole is in equilibrium, the torque due to the cable is equal in magnitude to the net torque due to the sign and the weight of the pole. Thus,

$$\tau_{\rm cable} = \tau_{\rm sign} + \tau_{\rm pole},$$

or

$$rF\sin\theta = \tau_{\rm sign} + \tau_{\rm pole},$$

and therefore

$$F = \frac{\tau_{\rm sign} + \tau_{\rm pole}}{r\sin\theta}.$$

Substituting different values of r and θ into this relationship can give you the relative sizes of the required cable forces.

Rank from largest to smallest. To rank items as equivalent, overlap them.

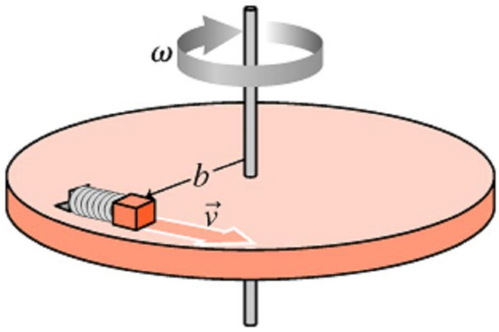
ANSWER:

View

Problem 11.52

Description: A massless spring of spring constant k is mounted on a turntable of rotational inertia I, as shown in the figure . The turntable is on a frictionless vertical axle, though initially it's not rotating. The spring is compressed a distance x from its...

A massless spring of spring constant k is mounted on a turntable of rotational inertia I, as shown in the figure . The turntable is on a frictionless vertical axle, though initially it's not rotating. The spring is compressed a distance x from its equilibrium, with a mass m placed against it. When the spring is released, the mass leaves the spring moving at right angles to a line through the center of the turntable, at a distance b from the center, and slides without friction across the table and off. Find expressions for (a) the linear speed of the mass and (b) the rotational speed of the turntable. *Hint*: What's conserved?



Part A

ANSWER:

$$v = \sqrt{\frac{Ikx^2}{m^2b^2 + mI}}$$

Part B

ANSWER:

$$\omega = \sqrt{\frac{kx^2mb^2}{(mb^2 + I)\,I}}$$

Problem 11.15

Description: A wheel is spinning about a horizontal axis, with angular speed omega and with its angular velocity pointing east. (a) Find the magnitude of its angular velocity after an angular acceleration of alpha, pointing 68 degree(s) west of north, is applied ...

A wheel is spinning about a horizontal axis, with angular speed 150 $\mathrm{rad/s}$ and with its angular velocity pointing east.

Part A

Find the magnitude of its angular velocity after an angular acceleration of 36 $\mathrm{rad/s^2}$, pointing 68 $^\circ$ west of north, is applied for 5.1 s.

Express your answer using two significant figures.

ANSWER:

$$\omega = \sqrt{(\omega - \alpha\cdot 0.927t)^2 + (0.375\alpha t)^2} \quad \mathrm{rad/s}$$

Part B

Find the direction of its angular velocity.

Express your answer using two significant figures.

ANSWER:

$$\frac{-\operatorname{atan}\left(\frac{\omega-\alpha\cdot 0.927t}{0.375\alpha t}\right)\cdot 180}{\pi}$$ ° west of north

Problem 11.45

Description: A circular bird feeder r in radius has rotational inertia I. The feeder is suspended by a thin wire and is spinning slowly at omega. A 140-g bird lands on the rim of the feeder, coming in tangent to the rim at 1.1 m/s in a direction opposite the...

A circular bird feeder 19 cm in radius has rotational inertia 0.19 $\mathrm{kg \cdot m^2}$. The feeder is suspended by a thin wire and is spinning slowly at 5.7 rpm. A 140-g bird lands on the rim of the feeder, coming in tangent to the rim at 1.1 $\mathrm{m/s}$ in a direction opposite the feeder's rotation.

Part A

What is the rotation rate after the bird lands?

Express your answer using two significant figures.

ANSWER:

$$\omega_2 = \frac{\frac{I\omega-.14\cdot 1.1r}{I+.14r^2}\cdot 60}{2\pi} \quad \mathrm{rpm}$$

Problem 11.56

Description: A d-cm-diameter phonograph record is dropped onto a turntable being driven at 33 (textstyle(1 over 3)) (rpm). (a) If the coefficient of friction between the record and turntable is mu, how far will the turntable rotate between the time when the...

A 40-cm-diameter phonograph record is dropped onto a turntable being driven at $33\frac{1}{3}\ \mathrm{rpm}$.

Part A

If the coefficient of friction between the record and turntable is 0.17, how far will the turntable rotate between the time when the record first contacts it and when the record is rotating at the full $33\frac{1}{3}\ \mathrm{rpm}$? Assume that the record is a homogeneous disk. *Hint:* You'll need to do an integral to calculate the torque.

Express your answer using two significant figures.

ANSWER:

$$\theta = \frac{3\left(\left(33+\frac{1}{3}\right)\cdot 2\frac{\pi}{60}\right)^2\frac{d}{2}}{4\mu\cdot 9.8}\frac{180}{\pi} \quad ^\circ$$

Problem 11.58

Description: When a star like our Sun no longer has any hydrogen or helium "fuel" for thermonuclear reactions in its core, it can collapse and become a white dwarf star. Often the star will "blow off" its outer layers and lose some mass before it collapses into...

When a star like our Sun no longer has any hydrogen or helium "fuel" for thermonuclear reactions in its core, it can collapse and become a white dwarf star. Often the star will "blow off" its outer layers and lose some mass before it collapses into the rapidly spinning, dense white dwarf. Suppose a star with mass 1.0 $\mathrm{M_{Sun}}$, with a radius of 6.96×10^8 m and rotating once every 25 days, becomes a white dwarf with a mass of 0.50 $\mathrm{M_{Sun}}$ and a rotation period of 131 s.

Part A

What is the radius of this white dwarf? (You may assume the progenitor star and the white dwarf star are both spherical.)

Express your answer using two significant figures.

ANSWER:

$$R = r\sqrt[3]{m2}\sqrt{\frac{131}{25\cdot 24\cdot 3600}} \quad \mathrm{m}$$

Part B

Compare your answer with the radius of the Sun and the radius of Earth.

Express your answer using two significant figures.

ANSWER:

$$\frac{R_{\mathrm{E}}}{R} = \frac{6370000}{r\sqrt[3]{m2}\sqrt{\frac{131}{25\cdot 24\cdot 3600}}}$$

Part C

Compare your answer with the radius of the Sun.

Express your answer using two significant figures.

ANSWER:

$$\frac{R_{\mathrm{Sun}}}{R} = \frac{6.96\cdot 10^{8}}{r\sqrt[3]{m2}\sqrt{\frac{131}{25\cdot 24\cdot 3600}}}$$

Score Summary:

Your score on this assignment is 0%.
You received 0 out of a possible total of 59 points.