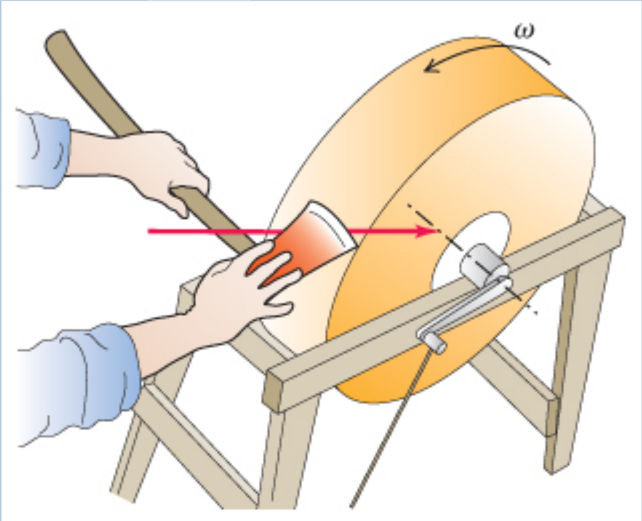
#29 Newton's Second Law Redux Post-class

Due: 11:00am on Wednesday, October 31, 2012

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

Exercise 10.13

A grindstone in the shape of a solid disk with diameter 0.510m and a mass of m = 50.0kg is rotating at ω = 850$\mathrm{rev/min}$. You press an ax against the rim with a normal force of F = 260N , and the grindstone comes to rest in 7.90s .



Part A

Find the coefficient of friction between the ax and the grindstone. You can ignore friction in the bearings.

ANSWER:

0.276

Correct

Exercise 10.25

A wheel with a weight of 389N comes off a moving truck and rolls without slipping along a highway. At the bottom of a hill it is rotating at an angular velocity of 23.1$\mathrm{rad/s}$. The radius of the wheel is 0.552m and its moment of inertia about its rotation axis is 0.800 MR^2. Friction does work on the wheel as it rolls up the hill to a stop, at a height of h above the bottom of the hill; this work has a magnitude of 3500J .

Part A

Calculate h.

Use 9.81$\mathrm{m/s^2}$ for the acceleration due to gravity.

ANSWER:

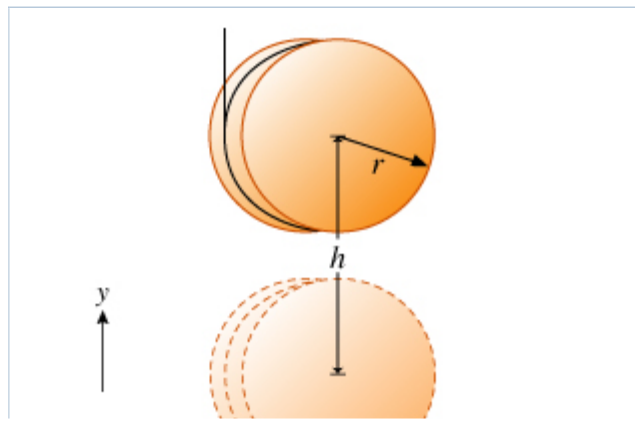
5.92 m

Correct

Unwinding Cylinder

A cylinder with moment of inertia I about its center of mass, mass m, and radius r has a string wrapped around it which is tied to the ceiling . The cylinder's vertical position as a function of time is $y(t)$.

At time $t = 0$ the cylinder is released from rest at a height h above the ground.



Part A

The string constrains the rotational and translational motion of the cylinder. What is the relationship between the angular rotation rate ω and v, the velocity of the center of mass of the cylinder?

Remember that upward motion corresponds to positive linear velocity, and counterclockwise rotation corresponds to positive angular velocity.

Express ω in terms of v and other given quantities.

Hint 1. Key to the constrained motion

Since the cylinder is wrapped about the string, it rolls without slipping with respect to the string. The constraint relationship to assure this kind of motion can be obtained by considering the velocity of the point on the cylinder that is in contact with the string--it should be zero.

Hint 2. Velocity of contact point

Find a *general* expression for the velocity of the point of contact.

Express your answer in terms of the velocity of the center of the cylinder, $v = dy(t)/dt$, r, and the rotation rate of the cylinder, ω.

Hint 1. How to approach this question

First, find the velocity of the contact point relative to the center of the cylinder. Since this ignores the translational motion of the entire cylinder with respect to the ground, you then need to add back in the cylinder's center-of-mass velocity to find the velocity of the contact point with respect to the ground.

ANSWER:

v_{contact} = $\omega r - v$

ANSWER:

$\omega = \frac{v}{r}$

Correct

Part B

In similar problems involving rotating bodies, you will often also need the relationship between angular acceleration, α, and linear acceleration, a. Find α in terms of a and r.

ANSWER:

$\alpha = \frac{a}{r}$

Correct

Part C

Suppose that at a certain instant the velocity of the cylinder is v. What is its *total* kinetic energy, $K_{\rm total}$, at that instant?

Express $K_{\rm total}$ in terms of m, r, I, and v.

Hint 1. Rotational kinetic energy

Find $K_{\rm rot}$, the kinetic energy of rotation of the cylinder.

Express your answer in terms of I and ω.

ANSWER:

K_{rot} = $\frac{1}{2}I\omega^2$

Hint 2. Rotational kinetic energy in terms of v

Now, use the results of Part A to express the rotational kinetic energy K_{rot} in terms of I, v, and r.

ANSWER:

K_{rot} = $\frac{1}{2}I\left(\frac{v}{r}\right)^2$

Hint 3. Translational kinetic energy

Find K_{trans}, the translational kinetic energy.

Express your answer in terms of m and v.

ANSWER:

K_{trans} = $\frac{1}{2}mv^2$

ANSWER:

K_{total} = $\frac{1}{2}v^2\left(m+\frac{I}{r^2}\right)$

Correct

Part D

Find $v_{\rm f}$, the cylinder's vertical velocity when it hits the ground.

Express $v_{\rm f}$, in terms of g, h, I, m, and r.

Hint 1. Initial energy

Find the cylinder's total mechanical energy when the cylinder is released from rest at height h. Take the gravitational potential energy to be zero at $y=0$.

Give your answer in terms of m, h, and the magnitude of the acceleration due to gravity, g.

ANSWER:

$E_{\rm i}$ = mgh

Hint 2. Energy conservation

Apply conservation of energy to this situation, to find the *total* kinetic energy of the cylinder just before it hits the ground $K_{\rm total}(y=0)$.

Your answer should involve h, and not $v_{\rm f}$.

ANSWER:

$K_{\rm total}(y=0) = mgh

ANSWER:

$v_{\rm f}$ = $-\sqrt{\frac{2mgh}{m+\frac{I}{r^2}}}$

Correct

Score Summary:

Your score on this assignment is 96%.
You received 28.8 out of a possible total of 30 points.