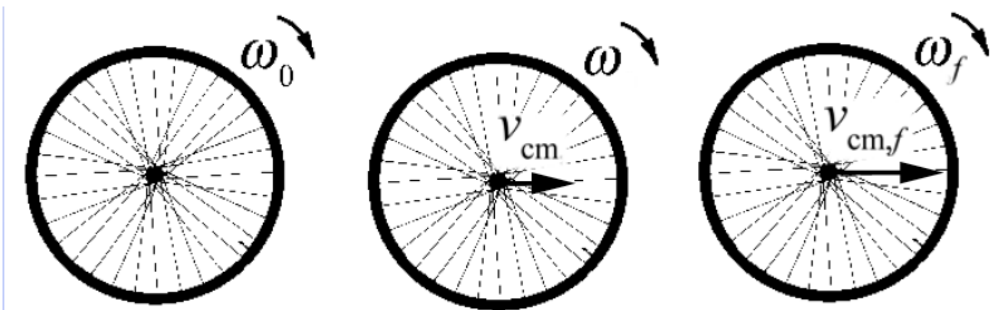
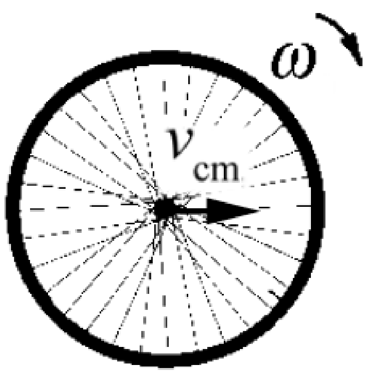
Two Dimensional Kinematics/Translation
Concept Question

Bicycle Wheel Solutions

Consider a bicycle wheel of radius R and mass m with moment of inertia I_{cm} about an axis passing perpendicular to the plane of the wheel and through the center-of-mass. The bicycle wheel is initially spinning with angular velocity ω_0 about the center-of-mass. The wheel is lowered to the ground without bouncing. As soon as the wheel touches the level ground, the wheel starts to accelerate forward until it begins to roll without slipping with a final angular velocity ω_f and center-of-mass velocity $v_{cm,f}$. Find the center-of mass velocity $v_{cm,f}$ when the wheel rolls without slipping.



Bicycle Wheel: Forces
How many forces (in a frame fixed to the ground) are acting on the bicycle when it is translating and rotating but is not yet rolling without slipping?



1. One.
2. Two.
3. Three.
4. Four.
5. Five.

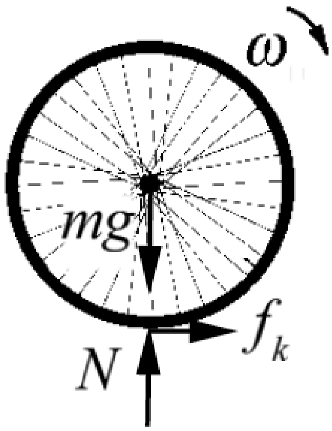
Bicycle Wheel: Direction of Kinetic Friction

What is the direction of the kinetic friction force on the bicycle wheel in the figure?

1. Points to the right.
2. Points to the left.
3. Points up.
4. Points down.

Bicycle Wheel: Torque about the Center-of-Mass

Is the torque about the center-of-mass zero?



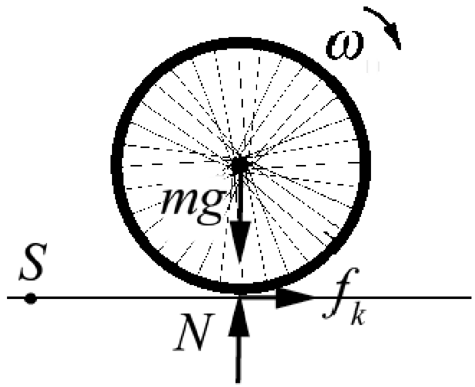
1. Yes.
2. No.
3. Not sure.

Bicycle Wheel: Angular Momentum about the Center-of-Mass
Is the angular momentum constant about the center-of-mass?

1. Yes.
2. No.
3. Not sure.

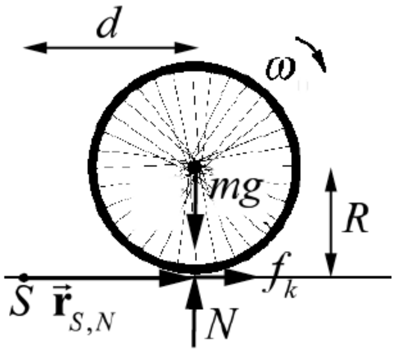
Bicycle Wheel: Torque about S due to Friction Force

Consider the point S shown in the figure. S lies on the line of contact between the wheel and the ground. Is the torque about S due to the kinetic friction force zero?



1. Yes.
2. No.
3. Not sure.

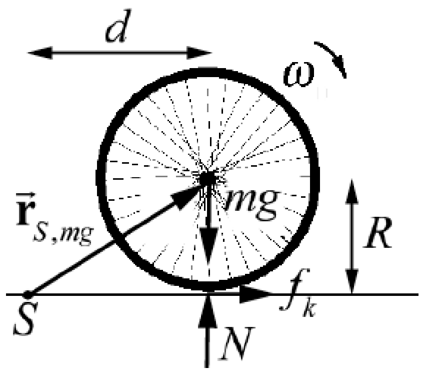
Bicycle Wheel: Torque about S due to Normal Force



Consider the point S shown in the figure. S lies on the line of contact between the wheel and the ground. Is the magnitude and direction of the torque about S due to the normal force

1. $\left|\vec{\boldsymbol{\tau}}_{S,N}\right| = Nd$, out of the page?
2. $\left|\vec{\boldsymbol{\tau}}_{S,N}\right| = Nd$, into the page?
3. $\left|\vec{\boldsymbol{\tau}}_{S,N}\right| = NR$, out of the page?
4. $\left|\vec{\boldsymbol{\tau}}_{S,N}\right| = NR$, into the page?
5. None of the above.

Bicycle Wheel: Torque about S due to Gravitational Force



Consider the point S shown in the figure. S lies on the line of contact between the wheel and the ground. Is the magnitude and direction of the torque about S due to the gravitational force

1. $\left|\vec{\boldsymbol{\tau}}_{S,F_{grav}}\right| = mgd$, out of the page?
2. $\left|\vec{\boldsymbol{\tau}}_{S,F_{grav}}\right| = mgd$, into the page?
3. $\left|\vec{\boldsymbol{\tau}}_{S,F_{grav}}\right| = mgR$, out of the page?
4. $\left|\vec{\boldsymbol{\tau}}_{S,F_{grav}}\right| = mgR$, into the page?
5. None of the above.

Bicycle Wheel: Torque about S

Do the torques about S due to the normal force and the gravitational force sum to zero?

1. Yes.
2. No.
3. Not sure.

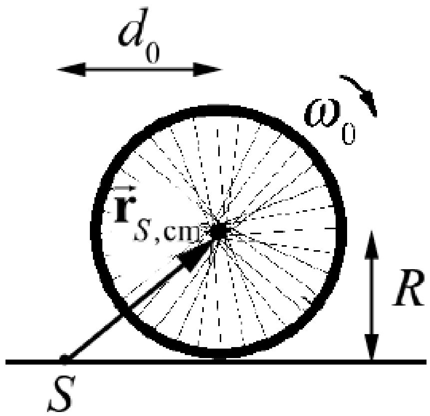
Bicycle Wheel: Angular Momentum about S

Is the angular momentum constant about the point S?

1. Yes.
2. No.
3. Not sure.

Bicycle Wheel: Initial Angular Momentum

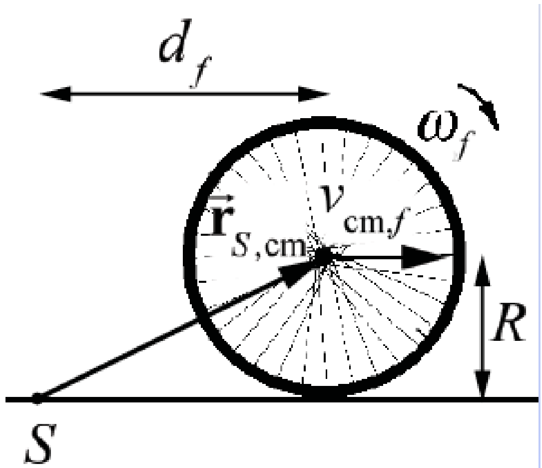
What is the magnitude and direction of the angular momentum of the wheel about the point S just before the wheel touches the ground?



1. $\left|\vec{\mathbf{L}}_{S,0}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,0}^{sys}\right| = mR\omega_0$, out of the page.
2. $\left|\vec{\mathbf{L}}_{S,0}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,0}^{sys}\right| = mR\omega_0$, into the page.
3. $\left|\vec{\mathbf{L}}_{S,0}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,0}^{sys}\right| = I_{cm}\omega_0$, out of the page.
4. $\left|\vec{\mathbf{L}}_{S,0}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,0}^{sys}\right| = I_{cm}\omega_0$, into the page.
5. $\left|\vec{\mathbf{L}}_{S,0}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,0}^{sys}\right| = md\omega_0$, into the page.
6. $\left|\vec{\mathbf{L}}_{S,0}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,0}^{sys}\right| = md\omega_0$, out of the page.
7. None of the above.

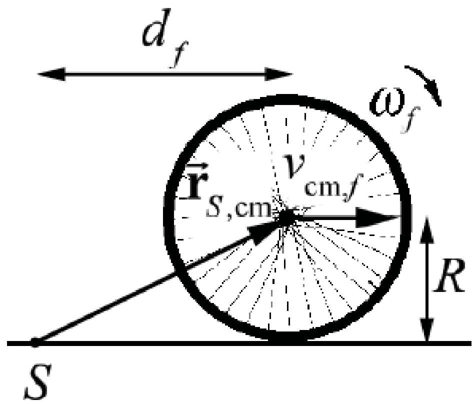
Bicycle Wheel: Final Angular Momentum

What is the magnitude and direction of the angular momentum of the wheel about the point S when the wheel is rolling without slipping?



1. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = -mRv_{cm,f} + I_{cm}\omega_f$, out of the page.
2. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = -mRv_{cm,f} + I_{cm}\omega_f$, into the page.
3. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = +md_f v_{cm,f} + I_{cm}\omega_f$, out of the page.
4. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = +md_f v_{cm,f} + I_{cm}\omega_f$, into the page.
5. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = +mRv_{cm,f} + I_{cm}\omega_f$, into the page.
6. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = +mRv_{cm,f} + I_{cm}\omega_f$, out of the page.
7. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = -md_f v_{cm,f} + I_{cm}\omega_f$, into the page.
8. $\left|\vec{\mathbf{L}}_{S,f}^{sys}\right| = \left|\vec{\mathbf{L}}_{cm,f}^{sys}\right| = -md_f v_{cm,f} + I_{cm}\omega_f$,out of the page.
9. None of the above.

Bicycle Wheel: Rolling Without Slipping



When the wheel is rolling without slipping what is the relation between the final center-of-mass velocity and the final angular velocity?

1. $v_{cm,f} = -R\omega_f$.
2. $\omega_f = Rv_{cm,f}$.
3. $v_{cm,f} = R\omega_f$.
4. $\omega_f = -Rv_{cm,f}$.

Bicycle Wheel: Final Centerof- Mass Velocity

What is the magnitude of the final center-of mass velocity when the wheel is rolling without slipping?

1. $v_{cm,f} = \dfrac{I_{cm}\omega_0}{I_{cm} - mR^2}$
2. $v_{cm,f} = \dfrac{I_{cm}\omega_0}{I_{cm} + mR^2}$
3. $v_{cm,f} = \dfrac{I_{cm}R\omega_0}{I_{cm} + mR^2}$
4. $v_{cm,f} = \dfrac{I_{cm}R\omega_0}{I_{cm} - mR^2}$
5. $v_{cm,f} = \dfrac{I_{cm}R\omega_0}{I_{cm} + mR}$
6. $v_{cm,f} = \dfrac{I_{cm}R\omega_0}{I_{cm} - mR}$
7. $v_{cm,f} = \dfrac{R\omega_0}{I_{cm} + mR^2}$
8. $v_{cm,f} = \dfrac{R\omega_0}{I_{cm} - mR^2}$
9. None of the above.