The angular velocity $\omega$ of any point on a solid object rotating about a fixed axis is the same. Both Bonnie & Klyde go around one revolution (2$\pi$ radians) every two seconds. Klyde’s angular velocity is:

1) same as Bonnie’s
2) twice Bonnie’s
3) half of Bonnie’s
4) 1/4 of Bonnie’s
5) four times Bonnie’s

ConcepTest 9.1a  Bonnie and Klyde I

Bonnie sits on the outer rim of a merry-go-round, and Klyde sits midway between the center and the rim. The merry-go-round makes one complete revolution every two seconds.

The angular velocity $\omega$ of any point on a solid object rotating about a fixed axis is the same. Both Bonnie & Klyde go around one revolution (2$\pi$ radians) every two seconds.

ConcepTest 9.1b  Bonnie and Klyde II

Bonnie sits on the outer rim of a merry-go-round, and Klyde sits midway between the center and the rim. The merry-go-round makes one revolution every two seconds. Who has the larger linear (tangential) velocity?

1) Bonnie
2) Klyde
3) both the same
4) linear velocity is zero for both of them

Their linear speeds $v$ will be different since $v = R\omega$ and Bonnie is located further out (larger radius $R$) than Klyde.

Follow-up: Who has the larger centripetal acceleration?

ConcepTest 9.2  Truck Speedometer

Suppose that the speedometer of a truck is set to read the linear speed of the truck, but uses a device that actually measures the angular speed of the tires. If larger diameter tires are mounted on the truck instead, how will that affect the speedometer reading as compared to the true linear speed of the truck?

1) speedometer reads a higher speed than the true linear speed
2) speedometer reads a lower speed than the true linear speed
3) speedometer still reads the true linear speed

The linear speed is $v = \omega R$. So when the speedometer measures the same angular speed $\omega$ as before, the linear speed $v$ is actually higher, because the tire radius is larger than before.

ConcepTest 9.3a  Angular Displacement I

An object at rest begins to rotate with a constant angular acceleration. If this object rotates through an angle $\theta$ in the time $t$, through what angle did it rotate in the time $1/2 \ t$?

1) 1/2 $\theta$
2) 1/4 $\theta$
3) 3/4 $\theta$
4) $2 \theta$
5) $4 \theta$

The angular displacement is $\theta = 1/2 \alpha t^2$ (starting from rest), and there is a quadratic dependence on time. Therefore, in half the time, the object has rotated through one-quarter the angle.
An object at rest begins to rotate with a constant angular acceleration. If this object has angular velocity \(\omega\) at time \(t\), what was its angular velocity at the time \(1/2t\)?

1) \(\frac{1}{2}\omega\)
2) \(\frac{1}{4}\omega\)
3) \(\frac{3}{4}\omega\)
4) \(2\omega\)
5) \(4\omega\)

The angular velocity is \(\omega = \alpha t\) (starting from rest), and there is a linear dependence on time. Therefore, in half the time, the object has accelerated up to only half the speed.

Using a Wrench

You are using a wrench to loosen a rusty nut. Which arrangement will be the most effective in loosening the nut?

Since the forces are all the same, the only difference is the lever arm. The arrangement with the largest lever arm (case #2) will provide the largest torque.

Follow-up: What is the difference between arrangement 1 and 4?

Two forces produce the same torque. Does it follow that they have the same magnitude?

1) yes
2) no
3) depends

Because torque is the product of force times distance, two different forces that act at different distances could still give the same torque.

Follow-up: If two torques are identical, does that mean their forces are identical as well?

In which of the cases shown below is the torque provided by the applied force about the rotation axis biggest? For all cases the magnitude of the applied force is the same.

1) \(F_1\)
2) \(F_2\)
3) \(F_3\)
4) all of them
5) none of them

The torque is:

\[\tau = F \cdot d \cdot \sin \theta\]

so the force that is at \(90^\circ\) to the lever arm is the one that will have the largest torque. Clearly, to close the door, you want to push perpendicular!!

Follow-up: How large would the force have to be for \(F_4\)?
**ConcepTest 9.7**

When a tape is played on a cassette deck, there is a tension in the tape that applies a torque to the supply reel. Assuming the tension remains constant during playback, how does this applied torque vary as the supply reel becomes empty?

1) torque increases  
2) torque decreases  
3) torque remains constant

As the supply reel empties, the lever arm decreases because the radius of the reel (with tape on it) is decreasing. Thus, as the playback continues, the applied torque diminishes.

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**ConcepTest 9.8a**

A force is applied to a dumbbell for a certain period of time, first as in (a) and then as in (b). In which case does the dumbbell acquire the greater center-of-mass speed?

1) case (a)  
2) case (b)  
3) no difference  
4) It depends on the rotational inertia of the dumbbell.

Because the same force acts for the same time interval in both cases, the change in momentum must be the same, thus the CM velocity must be the same.

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**Dumbbell I**

![Diagram of Dumbbell I](image)

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**ConcepTest 9.8b**

A force is applied to a dumbbell for a certain period of time, first as in (a) and then as in (b). In which case does the dumbbell acquire the greater energy?

1) case (a)  
2) case (b)  
3) no difference  
4) It depends on the rotational inertia of the dumbbell.

![Diagram of Dumbbell II](image)

If the CM velocities are the same, the translational kinetic energies must be the same. Because dumbbell (b) is also rotating, it has rotational kinetic energy in addition.

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**ConcepTest 9.9**

Two spheres have the same radius and equal masses. One is made of solid aluminum, and the other is made from a hollow shell of gold. Which one has the bigger moment of inertia about an axis through its center?

a) solid aluminum  
b) hollow gold  
c) same

Moment of inertia depends on mass and distance from axis squared. It is bigger for the shell since its mass is located farther from the center.

![Diagram of Moment of Inertia](image)
1. (20 pts) The box-fan is running at a speed of 0.875 revolutions/s in a clockwise (CW) direction when the motor is turned off. Due to the friction in the bearings, the fan slows down uniformly (i.e., at a constant rate) and it takes 0.955 s for the fan to come to a complete stop.

a) Determine the speed of point P immediately after the fan motor is turned off.

\[ \omega = \frac{0.875 \text{ rev}}{s} \left( \frac{2\pi \text{ rad}}{\text{rev}} \right) = 5.50 \text{ rad/s} \]

\[ \nu_p = \omega r_p = 5.50 \text{ rad/s} \left( 1.75 \text{ ft} \right) \]

\[ \nu_p = 9.62 \text{ ft/s} \]

\[ \alpha = \text{constant} \quad \Rightarrow \frac{\nu_p}{t} = \omega_0 + \alpha t \quad \Rightarrow \alpha = -\frac{\omega_0}{2} \]

\[ \alpha = -\frac{5.50 \text{ rad}}{0.955 \text{ s}} = -5.74 \text{ rad/s}^2 \]

\[ a_{n_p} = \omega^2 r_p = \left( 5.50 \text{ rad/s} \right)^2 \left( 1.75 \text{ ft} \right) = 52.9 \text{ ft/s}^2 \]

\[ a_{t_p} = \alpha r_p = \left( -5.74 \text{ rad/s}^2 \right) \left( 1.75 \text{ ft} \right) = -10.1 \text{ ft/s}^2 \]

\[ a_p = \sqrt{a_{n_p}^2 + a_{t_p}^2} = \sqrt{(-10.1 \text{ ft/s}^2)^2 + (52.9 \text{ ft/s}^2)^2} \]

\[ a_p = 53.9 \text{ ft/s}^2 \]
4. (20 pts) Two mass \( m_1 = m_2 = 3.15 \text{ kg} \) are connected to each other and to a central post by "mass less" cords and they are rotating at a constant rate of 0.875 revolutions/s on a smooth horizontal surface as shown. The radii of the masses are \( r_1 = 0.925 \text{ m} \) and \( r_2 = 1.25 \text{ m} \).

a) Determine the tension in the cord connecting the center post to \( m_1 \).

b) Determine the tension in the cord connecting the two masses.

\[
\begin{align*}
T_1 & = T_2 + m_1 \frac{(\omega r_1)^2}{r_1} \\
T_1 - T_2 & = m_1 \frac{\omega^2}{r_1}
\end{align*}
\]

For \( m_1 \):
\[
\sum F = m_1 a_{n_1}
\]
\[
T_1 - T_2 = m_1 \frac{\omega^2}{r_1}
\]

For \( m_2 \):
\[
\sum F = m_2 a_{n_2}
\]
\[
T_2 = m_2 \frac{\omega^2}{r_2} = m_2 \frac{(\omega r_2)^2}{r_2}
\]

\[
T_2 = 3.15 \text{ kg} \left[ \frac{5.498 \text{ rad/s}}{5} \right]^2 (1.25 \text{ m}) = 119 \text{ N}
\]

\[ T_1 = 207 \text{ N} \]

\[
T_1 = 119 \text{ N} + 3.15 \text{ kg} \left[ \frac{5.498 \text{ rad/s}}{5} \right]^2 (0.925 \text{ m}) = 119 \text{ N} + 88 \text{ N}
\]