Spring 2014

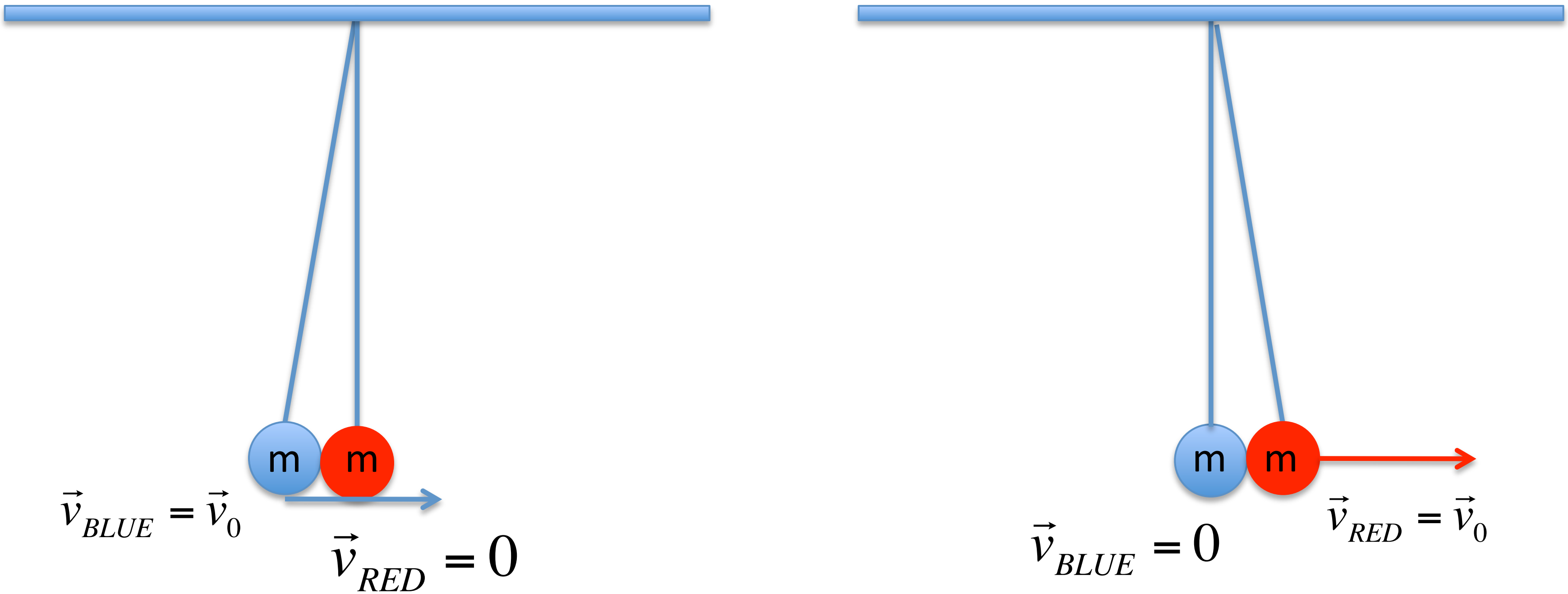
PHYS-2010

Lecture 30

Clicker Question

Room Frequency BA

Consider a suspended blue sphere that collides **elastically** with a suspended red sphere of the same mass.



After impact, is the situation at right possible:

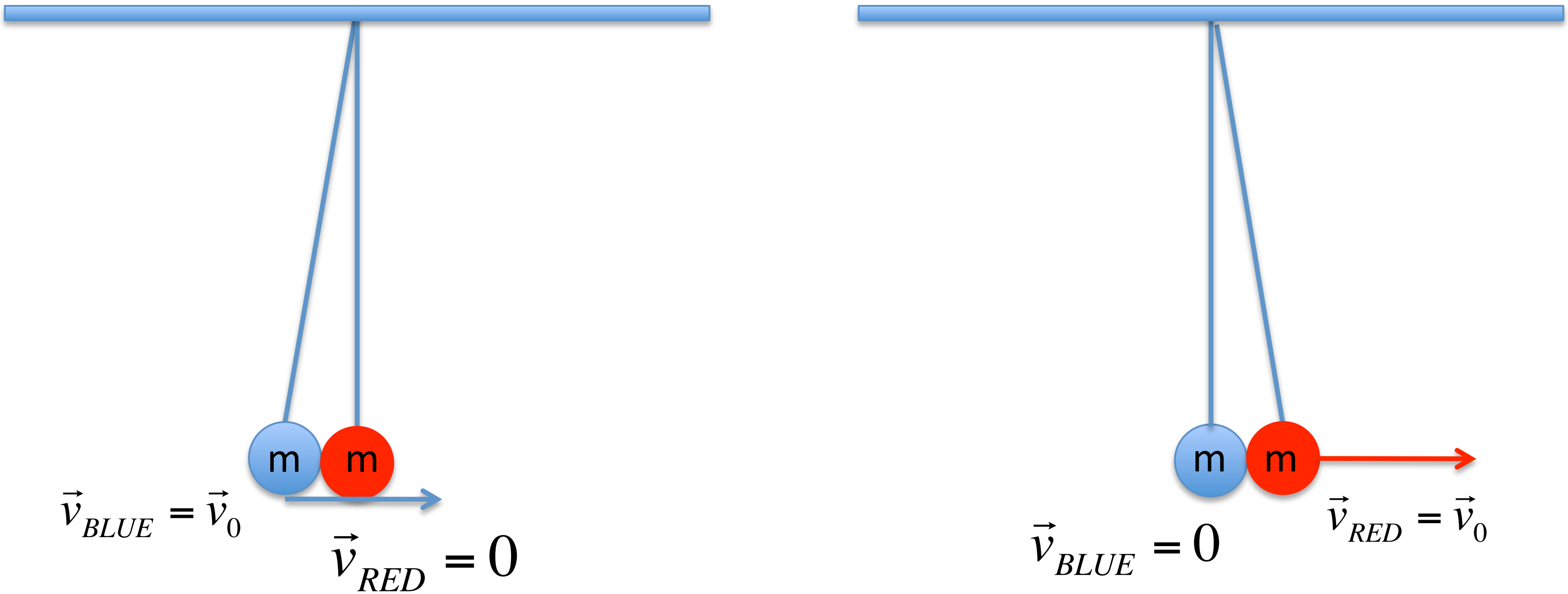
A) Yes

B) No

Clicker Question

Room Frequency BA

Consider a suspended blue sphere that collides **elastically** with a suspended red sphere of the same mass.

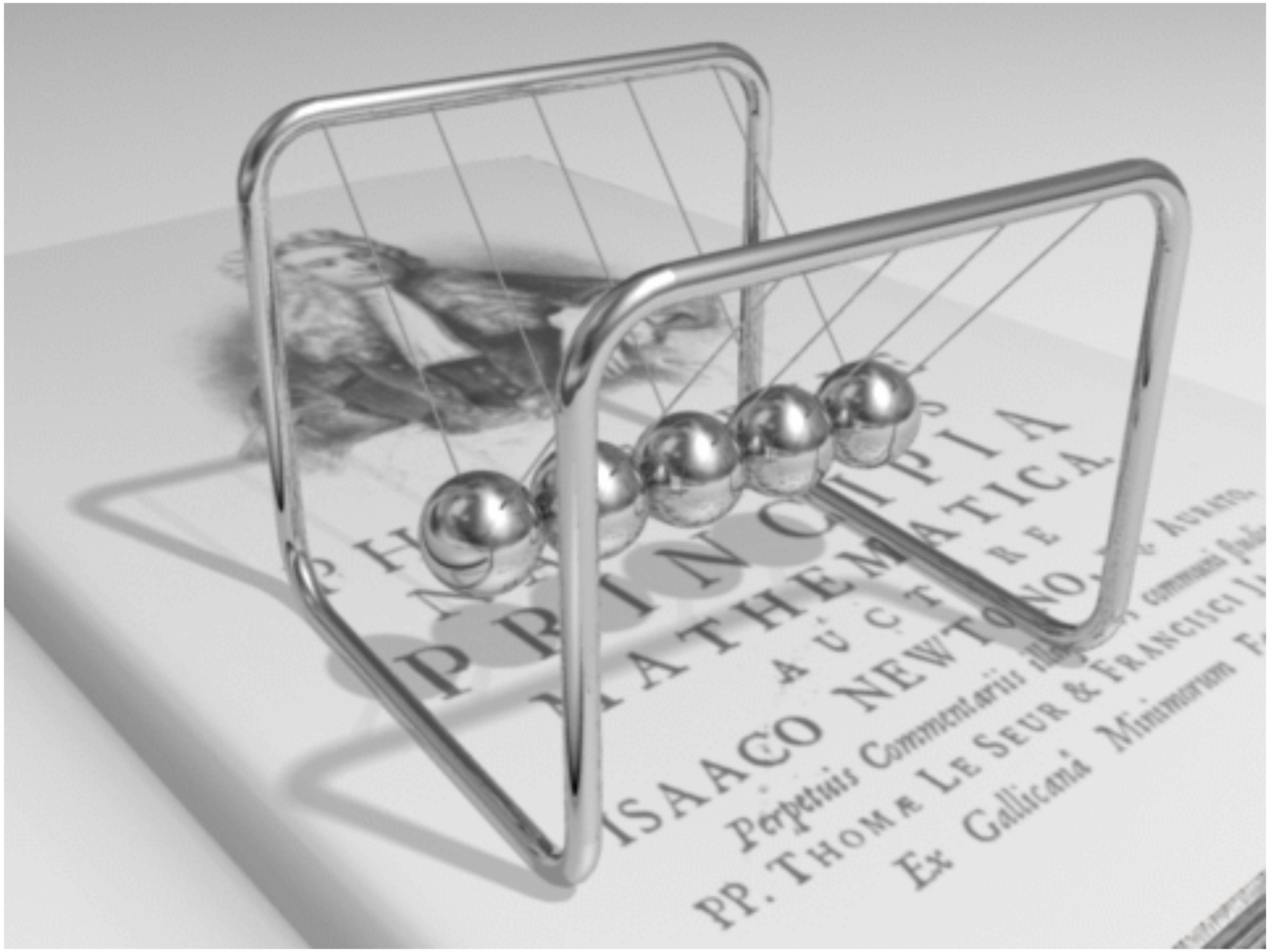


After impact, is the situation at right possible:

A) Yes

B) No

Newton’s Cradle



Announcements

- Read Giancoli **Chapter 8 on Rotational Motion**.
- **CAPA 10 deadline postponed until Thur., Apr. 3, 11 pm !!!**
- **N**ext CAPA # 11 due April 8.
- Written **Homework # 8** due this Friday, April 4.
- This week in Section: **Lab # 6** "Momentum" with **Prelab**.
- Next week: Review Recitation and **missed Lab make-up.**

  - at least 7 labs are required to pass the course;

  - contact your TA to arrange lab makeup ahead of time. You will need to attend twice: (1) for lab make-up; and (2) for review recitation. You can attend any other section (in addition to your regular one), with that section's TA advance permission.

- **Study Session** by Prof. Pollock: Apr. 1 and 8, 5-6pm, G125.
- **Midterm Exam 3** on Thursday, April 10, 7:30 pm.

ROTATIONAL MOTION

Rotational Motion

Motion of a "rigid" body about a fixed axis of rotation.

Translation	$\leftrightarrow$	**Rotation**
x	$\leftrightarrow$	θ
$v = \dfrac{\Delta x}{\Delta t}$	$\leftrightarrow$	$\omega = \dfrac{\Delta \theta}{\Delta t} = \dfrac{v}{r}$
$a = \dfrac{\Delta v}{\Delta t}$	$\leftrightarrow$	$\alpha = \dfrac{\Delta \omega}{\Delta t} = \dfrac{a_{tan}}{r}$
F	$\leftrightarrow$	$\tau = r\,F_{\perp}$
M	$\leftrightarrow$	$I = \sum m\,r^2$
$F_{net} = M\,a$	$\leftrightarrow$	$\tau_{net} = I\,\alpha$
$KE_{trans} = (1/2)M\,v^2$	$\leftrightarrow$	$KE_{rot} = (1/2)\,I\,\omega^2$
$p = m\,v$	$\leftrightarrow$	$L = I\,\omega$
$F_{net}\Delta t = \Delta p$	$\leftrightarrow$	$\tau_{net}\Delta t = \Delta L$
$\Delta KE + \Delta PE = \text{constant}$	$\leftrightarrow$	$\Delta KE_{trans} + \Delta KE_{rot} + \Delta PE = \text{constant}$

Conservation of mechanical energy

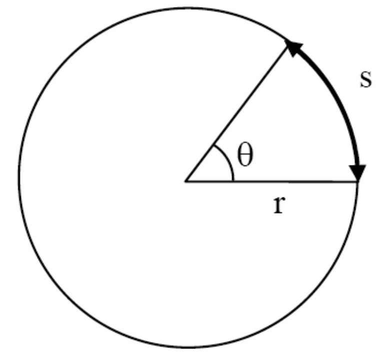
NII for rotations

Conservation of angular momentum

Rotational Motion

Motion of a "rigid" body about a fixed axis of rotation.

Translation	$\leftrightarrow$	**Rotation**
x	$\leftrightarrow$	θ
		angle of rotation (rads)



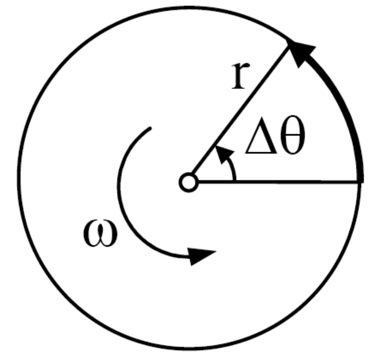
polar coordinates

Rotational Motion

Motion of a "rigid" body about a fixed axis of rotation.

Translation	$\leftrightarrow$	**Rotation**
x	$\leftrightarrow$	θ
$v = \dfrac{\Delta x}{\Delta t}$	$\leftrightarrow$	$\omega = \dfrac{\Delta \theta}{\Delta t}$

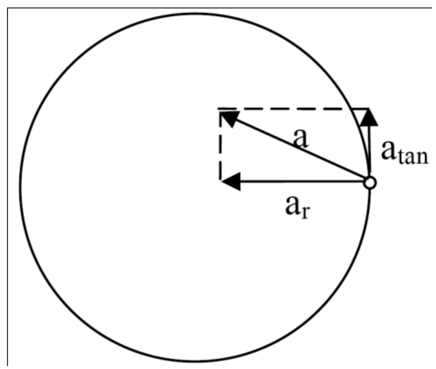
angular velocity (rad/s)



Rotational Motion

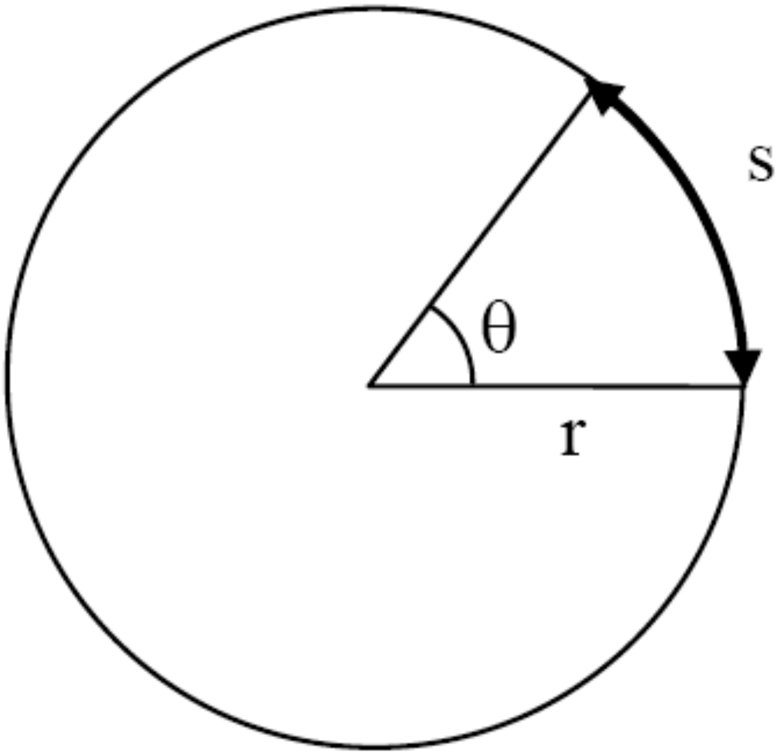
Motion of a "rigid" body about a fixed axis of rotation.

Translation	$\leftrightarrow$	**Rotation**
x	$\leftrightarrow$	θ
$v = \dfrac{\Delta x}{\Delta t}$	$\leftrightarrow$	$\omega = \dfrac{\Delta \theta}{\Delta t} = \dfrac{v}{r}$
$a = \dfrac{\Delta v}{\Delta t}$	$\leftrightarrow$	$\alpha = \dfrac{\Delta \omega}{\Delta t} = \dfrac{a_{tan}}{r}$



angular acceleration (rad/s²)

Rotational Kinematics



Remember: $s = r\,\theta$ (θ: rads)

(r,θ) polar coordinates

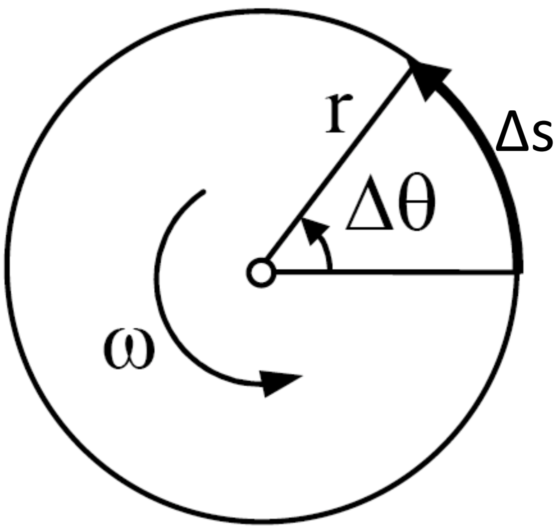
For circular motion, θ completely describes the motion.
It gives the "rotational position".

Circumference: $C = 2\pi r$ 360° = 2π rad

180° = π rad

57.3° = 1 rad

Rotational Kinematics



$s = r\,\theta$ arc-length formula

$$v = \frac{\Delta s}{\Delta t}$$ tangential velocity (m/s)

$$= \frac{\Delta(r\theta)}{\Delta t}$$ use arc-length formula

$$= r\frac{\Delta\theta}{\Delta t}$$ *r* = const for circular motion

$$= r\omega$$ define: **angular velocity** ω

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r}$$ Rate at which θ is changing

Clicker Question

Room Frequency BA

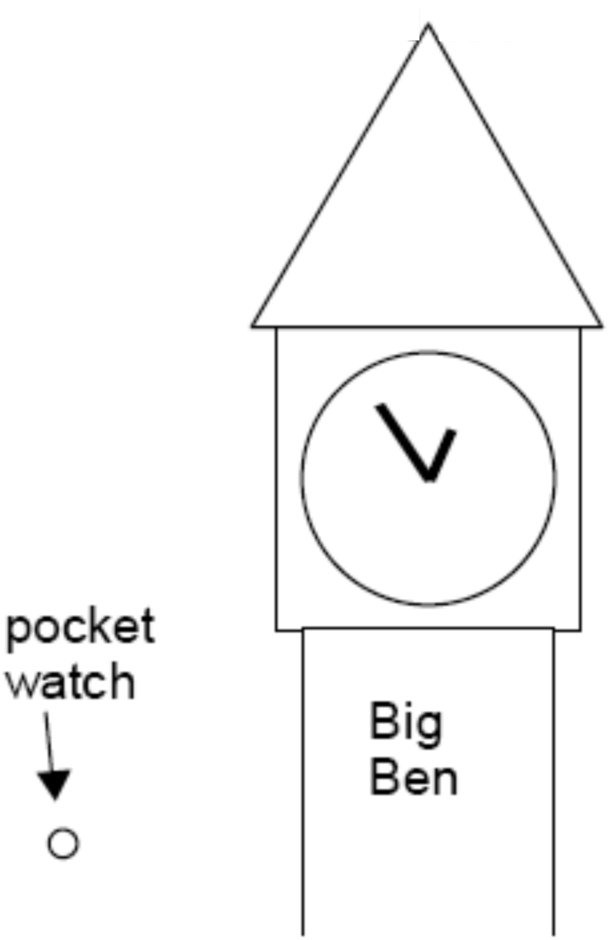
A pocket watch and Big Ben are both keeping perfect time.

Which minute hand has larger ***angular velocity ω***?

A) Pocket watch.

B) Big Ben.

C) Same ω.



Clicker Question

Room Frequency BA

A pocket watch and Big Ben are both keeping perfect time.

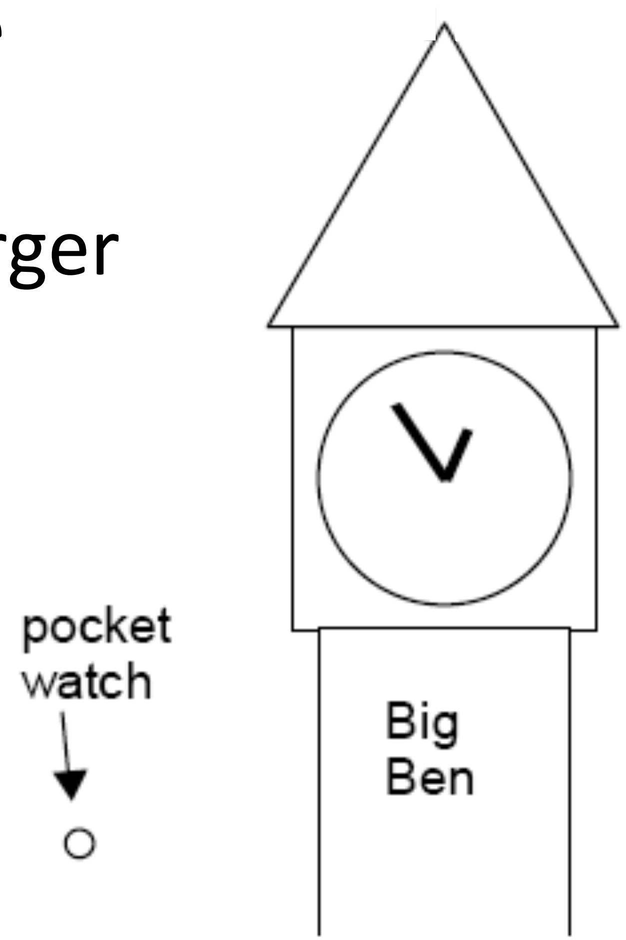
Which minute hand's tip has larger ***tangential velocity v***?

A) Pocket watch.

B) Big Ben.

C) Same *v*.

$v = r\omega$



Clicker Question

Room Frequency BA

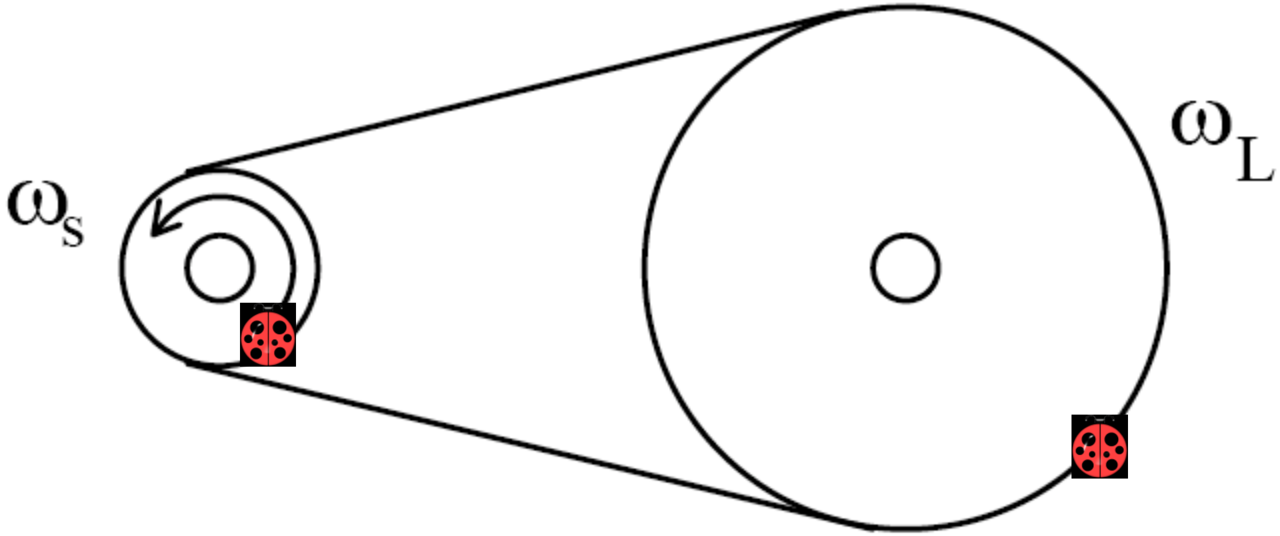
A small wheel and a large wheel are connected by a belt. The small wheel turns at a constant angular velocity ω_S.

There is a bug *S* on the rim of the small wheel and a bug *L* on the rim of the big wheel. How do their speeds compare?

A) $v_S = v_L$

B) $v_S > v_L$

C) $v_S < v_L$



Clicker Question

Room Frequency BA

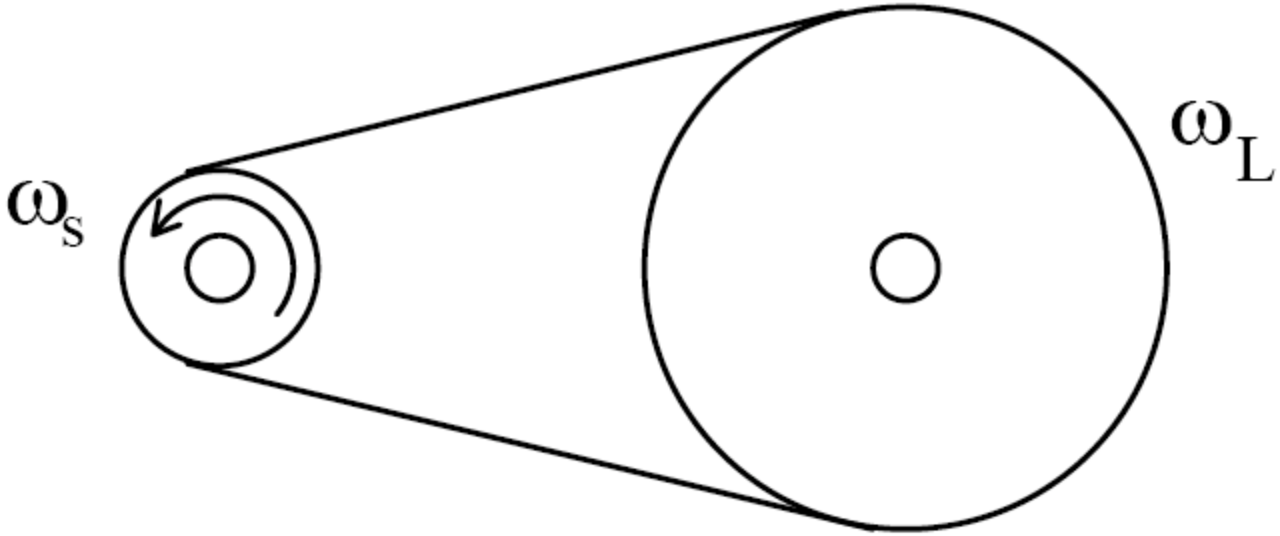
A small wheel and a large wheel are connected by a belt. The small wheel turns at a constant angular velocity ω_S.

How does the magnitude of the angular velocity of the large wheel ω_L compare to that of the small wheel ω_S?

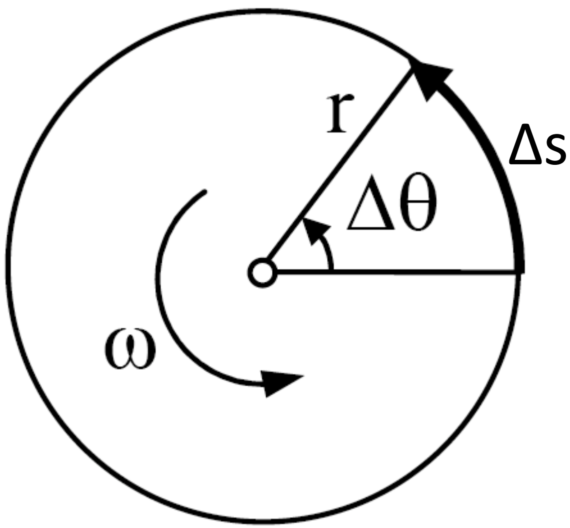
A) $\omega_S = \omega_L$

B) $\omega_S > \omega_L$

C) $\omega_S < \omega_L$



Rotational Kinematics



$s = r\,\theta$ arc-length formula

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r}$$ angular velocity

Units:

$$f = \frac{\#\,revolutions}{\sec} = \frac{1\ rev}{period} = \frac{1}{\tau} \quad (\mathrm{Hz})$$

$$\omega = \frac{\#\,radians}{\sec} = \frac{2\pi}{period} = \frac{2\pi}{\tau} = 2\pi f$$

$$v = \omega r = \frac{2\pi r}{\tau} = 2\pi r f$$

Note:

rpm = 60 f = 60/τ

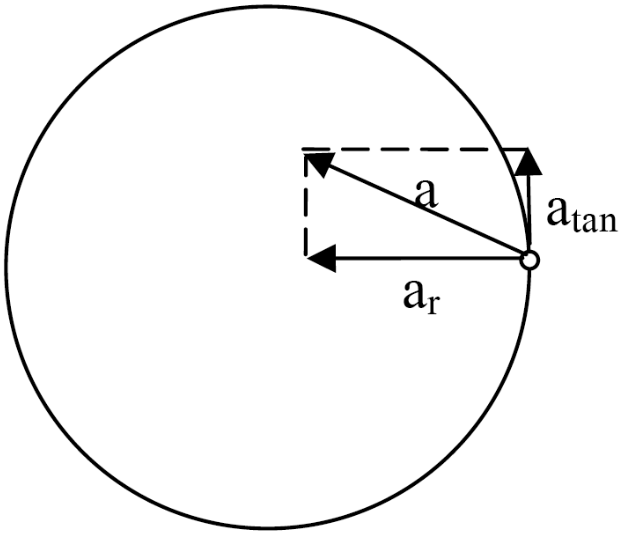
Rotational Kinematics

$s = r\,\theta$

arc-length formula

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{v}{r}$$

Rate at which θ is changing



$$a_{tan} = \frac{\Delta v}{\Delta t}$$ tangential acceleration (m/s^2)

$$= \frac{\Delta(r\omega)}{\Delta t}$$ use equation for ω

$$= r\frac{\Delta\omega}{\Delta t}$$ *r* = const for circular motion

$$= r\alpha$$ define: **angular acceleration** α

a_r is due to change in direction of velocity vector $\vec{v}$ (centripetal accel)

a_{tan} is due to change in the magnitude (speed) of $\vec{v}$

$$|\vec{a}| = a = \sqrt{a_{tan}^2 + a_r^2}$$

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{a_{tan}}{r}$$

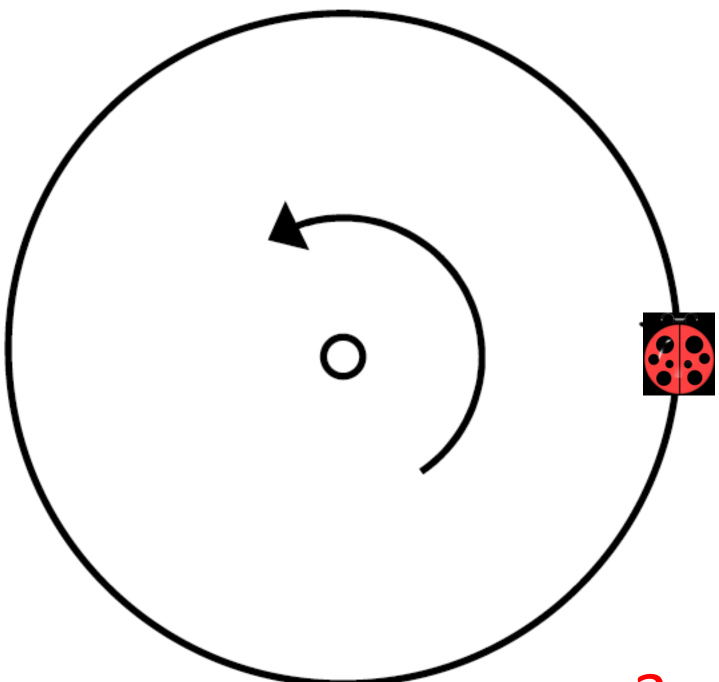
Rate at which ω is changing

Clicker Question

Room Frequency BA

A ladybug is clinging to the rim of a wheel spinning CCW.

Assuming that the wheel is **spinning at a constant rate**, what is the direction of her acceleration when she's at the far right?



A) ↙

B) ↑

C) →

D) ←

E) ↖

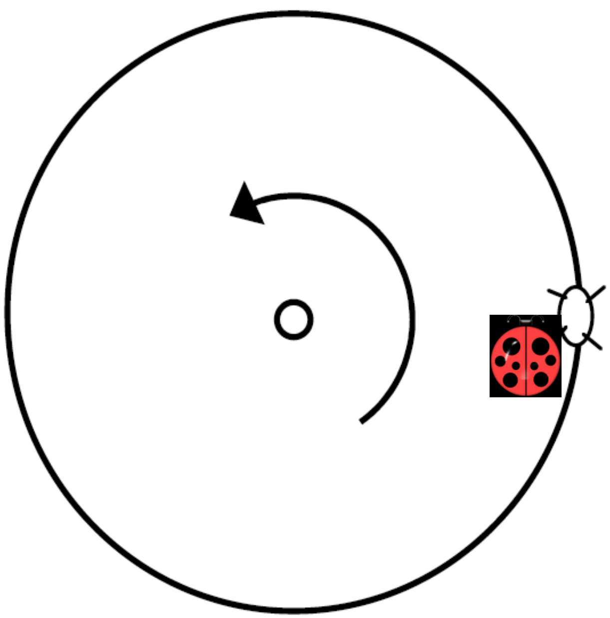
Since her speed is constant, $a_{tan} = 0$, so the only acceleration is centripetal acceleration pointing toward the center of the wheel.

Clicker Question

Room Frequency BA

A ladybug is clinging to the rim of a wheel spinning CCW.

Assuming that the wheel is **speeding up**, what is the direction of her acceleration when she's at the far right?



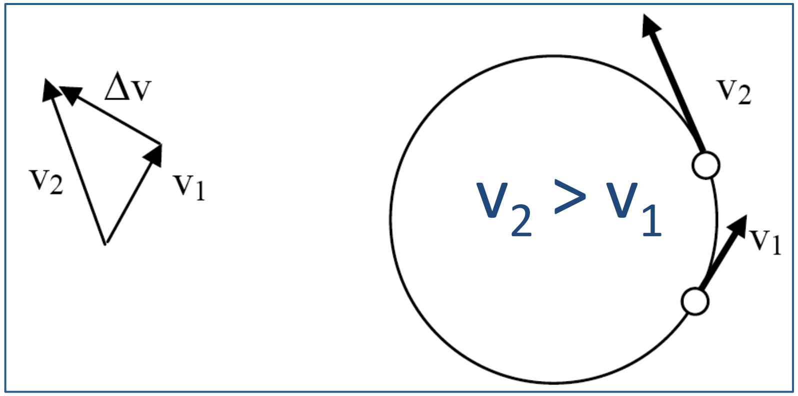
A) ↙

B) ↑

C) →

D) ←

E) ↖



Rotational Kinematics

Translation	↔	Rotation	
x	↔	θ	angle of rotation (rads)
$v = \dfrac{\Delta x}{\Delta t}$	↔	$\omega = \dfrac{\Delta\theta}{\Delta t} = \dfrac{v}{r} = \dfrac{2\pi}{\tau} = 2\pi f$	angular velocity (rad/s)
$a = \dfrac{\Delta v}{\Delta t}$	↔	$\alpha = \dfrac{\Delta\omega}{\Delta t} = \dfrac{a_{\tan}}{r}$	angular acceleration (rad/s^2)

Constant acceleration *a*:		Constant angular acceleration α:
$v = v_0 + at$	↔	$\omega = \omega_0 + \alpha t$
$x = x_0 + v_o t + \dfrac{1}{2}at^2$	↔	$\theta = \theta_0 + \omega_o t + \dfrac{1}{2}\alpha t^2$
$v^2 = v_0^2 + 2a\Delta x$	↔	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$