(RK.L2.1) Familiarize Stage

Thursday, March 29, 2018 8:34 PM

Rotational Kinematics (RK)

Familiarization Stage:

Pre-lecture 2: Connecting Rotational and Translational Kinematics

Reading

1. Read

Lecture Videos

1. Watch

Example Problems

1. Watch

Simulations

1. Sim

Other Suggested Content

1. Check out

Practice

1. Try

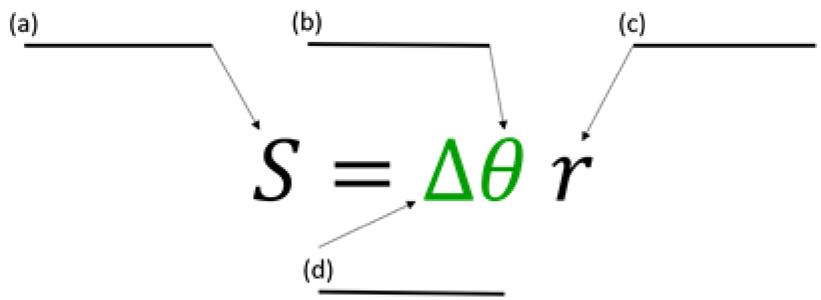
Homework

RK.L2.1-01

Description: Infographic quiz arc length - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Radius, (2) Arc length, (3) Change in, (4) Angular position



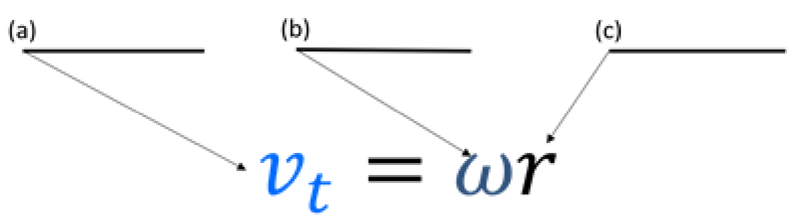
Answer: (a) Arc length, (b) Angular position, (c) Radius, (d) Change in

RK.L2.1-02

Description: Infographic quiz tangential component of velocity - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Angular velocity, (2) Tangential velocity, (3) Radius



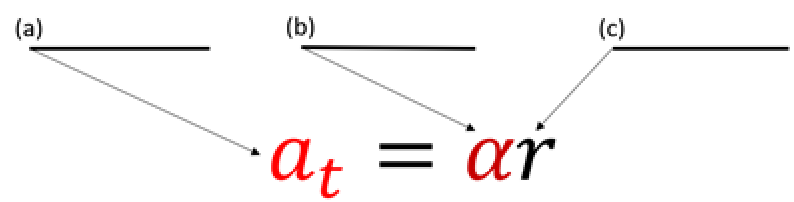
Answer: (a) Tangential velocity, (b) Angular velocity, (c) Radius

RK.L2.1-03

Description: Infographic quiz tangential component of acceleration - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Angular acceleration, (2) Tangential component of acceleration, (3) Radius



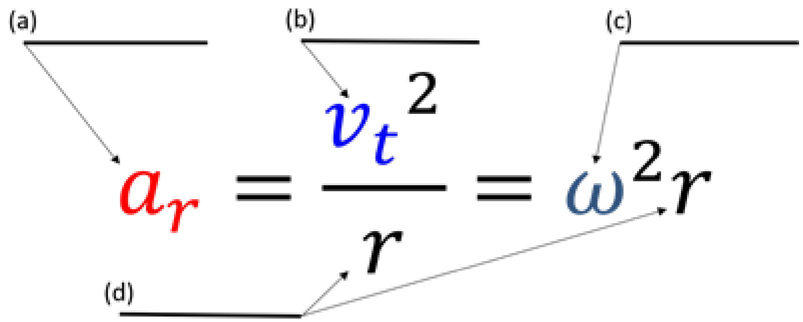
Answer: (a) Tangential component of acceleration, (b) Angular acceleration, (c) Radius

RK.L2.1-04

Description: Infographic quiz radial component of acceleration - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Match each term in the equation with the correct description from the following list. (1) Radius, (2) Angular velocity, (3) Tangential component of velocity, (4) Radial component of acceleration



Answer: (a) Radial component of acceleration, (b) Tangential component of velocity, (c) Angular velocity, (d) Radius

RK.L2.1-05

Description: Graphical representation of kinematics - going between position, velocity, and acceleration

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: You're given a plot of position as a function of time.

(a) What graphical operation will helps determine the velocity at a specific time?

(1) Average slope of the position curve
(2) Instantaneous slope of the position curve
(3) Height of the position curve
(4) The tangent to the position curve
(5) Area under the position curve

(6) Curvature of the position curve

Answer: (2), (4)

(b) What graphical operation helps determine the acceleration at a specific time?

(1) Average slope of the position curve
(2) Instantaneous slope of the position curve
(3) Height of the position curve
(4) The tangent to the position curve
(5) Area under the position curve
(6) Curvature of the position curve

Answer: (6)

RK.L2.1-06

Description: Graphical representation of kinematics - going between position, velocity, and acceleration

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: You're given a plot of velocity as a function of time.

(a) What graphical operation helps determine the acceleration at a specific time?

(1) Average slope velocity curve	
(2) Instantaneous slope velocity curve	
(3) Height of the velocity curve	
(4) The tangent to the velocity curve	
(5) Area under the velocity curve	
(6) Curvature of the velocity curve	

Answer: (2), (4)

(d) What graphical operation helps determine the change in position?

(1) Average slope velocity curve
(2) Instantaneous slope velocity curve
(3) Height of the velocity curve
(4) The tangent to the velocity curve
(5) Area under the velocity curve
(6) Curvature of the velocity curve

Answer: (5)

RK.L2.1-07

Description: Finding distance traveled from number of rotations

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: The Brazilian three-banded armadillo has a hard outer exterior and rolls into a ball for protection. Suppose Army the armadillo rolls into a ball with a 5 cm radius. They are near a hill and begin to roll down it.

(a) After 45.8 revolutions, how many radians have they undergone?

(1) 45.8 radians
(2) 91.6 radians
(3) 288 radians
(4) 1240 radians
(5) 16,500 radians

Answer: (3)

(a) After 45.8 revolutions, how far as Army travelled?

(1) 14.4 m

(2) 28.8 m
(3) 56.6 m
(4) 128 m
(5) 256 m

Answer: (1)

RK.L2.1-0x

Description: One (or two) sentence quick description of the problem

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: Write the problem statement here

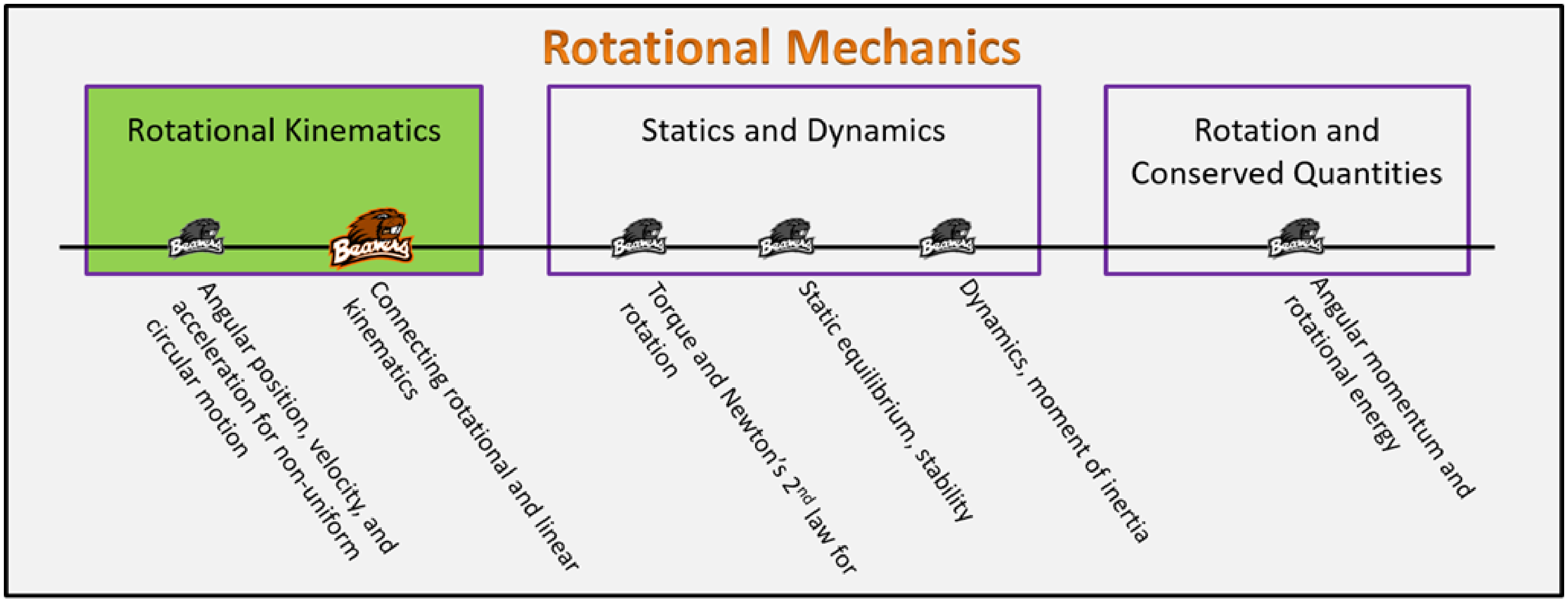
Answer: x

(RK.L2.2.sols) Foundation Stage Solutions

Monday, January 22, 2018 5:44 PM

Rotational Kinematics
Foundation Stage (RK.2.L2)

lecture 2
Connecting rotational and linear kinematics



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (rotational kinematics)
- **Knight** (College Physics : A strategic approach 3rd) :: 7.1 ; 7.2
- ***Knight** (Physics for Scientists and Engineers 4th) :: 4.4 ; 4.5 ; 4.6 ; 12.1
- **Giancoli** (Physics Principles with Applications 7th) :: 8-2

Warm up

RK.2.L2-1:

Description: Given initial and final angular velocity and time, determine the average angular acceleration.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: It takes about 0.75 seconds to start a car. When the car is started, the engine's crankshaft is spinning at 1,500 RPM. What is the average acceleration of the engine's crankshaft?

(1) 33.3 rad/s^2
(2) 118 rad/s^2
(3) 209 rad/s^2
(4) 2000 rad/s^2

$$\bar{\alpha} = \frac{\Delta\omega}{\Delta t}$$

$$\bar{\alpha} = \frac{\omega_f - \omega_i}{\Delta t}, \quad \omega_i = 0$$

$$\bar{\alpha} = \frac{\omega_f}{\Delta t}$$

$$\bar{\alpha} = \frac{2\pi f_f}{\Delta t}$$

$$\bar{\alpha} = \frac{2\pi\left(25\ \frac{\text{REV}}{\text{S}}\right)}{0.75\ \text{SEC}}$$

$$\bar{\alpha} \approx 209\ \frac{\text{RAD}}{\text{S}^2}$$

SI

$$1500\ \frac{\text{REV}}{\text{MIN}} \times \frac{1\ \text{MIN}}{60\ \text{SEC}} = 25\ \frac{\text{REV}}{\text{SEC}}$$

Selected Learning Objectives

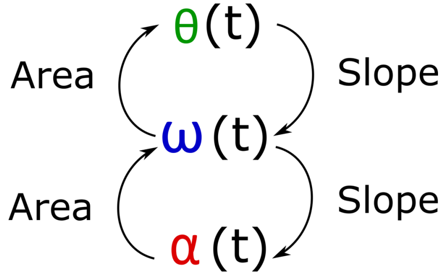
1. Coming soon to a lecture template near you.

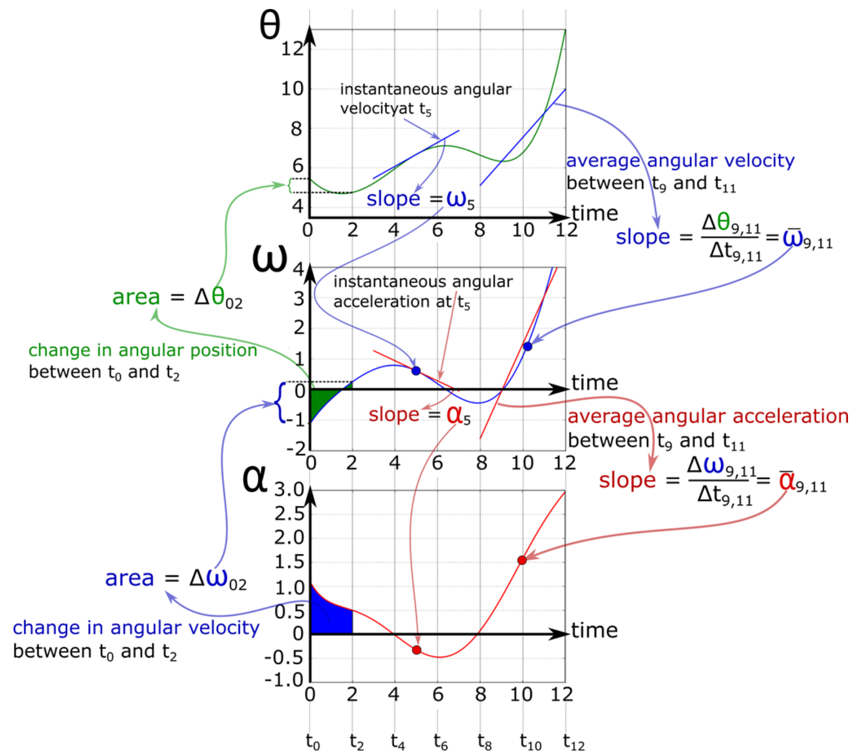
Key Terms

- Arc length (i.e. linear distance or distance)
- Rotational kinematics physical representation

Key Equations

GRAPHICAL ANALYSIS





ROTATIONAL KINEMATICS

Change in angular position (angular displacement)

Initial angular velocity

angular acceleration

$$\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha\Delta t^2$$

Change in time

In words: The change in the angular position is equal to the initial angular velocity multiplied by the change in time plus one-half of the angular acceleration multiplied by the change in time squared.

Final angular velocity

Initial angular velocity

angular acceleration

Change in time

$$\omega_f = \omega_i + \alpha \Delta t$$

In words: The final angular velocity is equal to the initial angular velocity plus the angular acceleration multiplied by the change in time.

Final angular velocity

Initial angular velocity

angular acceleration

Change in angular position (angular displacement)

$$\omega_f^2 = \omega_i^2 + 2 \alpha \Delta\theta$$

In words: The final angular velocity squared is equal to the initial angular velocity squared plus two times the angular acceleration multiplied by the change in the angular position.

CONNECTING ROTATIONAL TO LINEAR

Arc length

Change in angular position (angular displacement) *Must be in radians

$$s = r\,\Delta\theta$$

Radius of circular path

Tangential component of velocity

Angular velocity *Must be in rad/time

$$v_t = \omega\, r$$

Radius of circular path

In words: The arc length (i.e. linear distance) an object travels is equal to the radius of the circular path the object is traveling multipled by the angular displacement the object goes through.

In words: The tangential component of velocity is equal to the angular velocity times the radius of the circular path the object is traveling around.

Radial component of acceleration

Tangential component of velocity

Angular velocity *Must be in rad/time

$$a_r = \frac{v_t^2}{r} = \omega^2 r$$

Radius of circular path

Tangential component of acceleration

Angular acceleration *Must be in rad/time^2

$$a_t = \alpha\, r$$

Radius of circular path

In words: The tangential component of acceleration is equal to the angular acceleration times the radius of the circular path the object is traveling.

In words: The radial component of acceleration is equal to the tangential component of velocity squared divided by the radius of the circular path the object is traveling. The radial component of acceleration is also equal to the angular velocity squared times the radius of the circular path the object is traveling.

Key Concepts

- Graphical analysis for rotational kinematics is analogous to graphical representation for regular linear kinematics.

- A physical representation for a rotational kinematics analysis should include the following quantities: trajectory (for rotational kinematics this will always be a circle or circular arc), at least 2 dots representing the object at two different snapshots in time, angular velocity at each snapshot represented with curvy lines to show weather positive or negative, angular acceleration between a set of snapshots represented with a curvy line to show weather positive or negative, and the angular displacement between a set of snapshots represented with a curvy line to show weather positive or negative.
- The arc length (S) is a positive scalar quantity that represents the linear distance an object would have traveled if it the object traveled in a straight line rather than in a circle. In general, the arc length is the distance along a curved path. When using the mathematical representation of arc length, be sure to use units of radians for the angular displacement else the above key equation won't result in the proper arc length.
- Linear quantities such as distance traveled can be related to rotational quantities.

Questions

Act I: Graphical representation - slopes and areas

RK.2.L2-2:

Description: Use an angular velocity vs time graph to determine angular acceleration and angular displacement. Sketch the corresponding angular acceleration and angular displacement graphs as a function of time given angular velocity vs time. (1 minute + 2 minutes + 3 minutes + 2 minutes + 3 minutes)

$\omega(t=3s) \approx 0.5\ \frac{RAD}{s}$

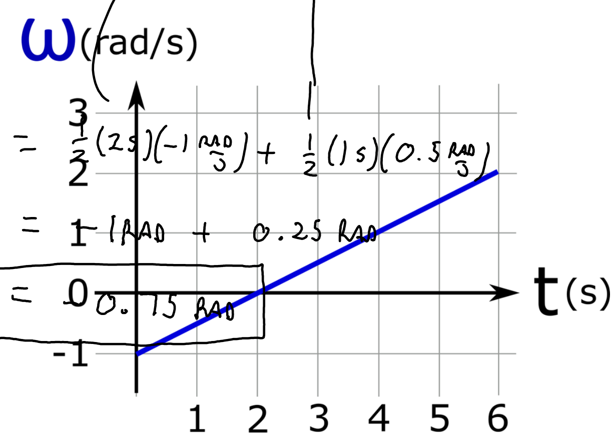
Learning Objectives: [1, 12, 13]

Problem Statement: Danny Johnson the DJ spins a disk whose angular velocity is plotted as a function of time as shown below. The disk initially started at $\theta_0 = 0$ radians.

$\alpha = \frac{(1-0)\ \frac{RAD}{s}}{(4-2)\ s} = 0.5\ \frac{RAD}{s^2}$

(a) What is the angular velocity of the disk at **t** = 3 seconds?

(b) What is the angular acceleration of the disk at **t** = 3 seconds?



$\text{AREA} = \Delta\theta = \frac{1}{2}(2s)(-1\ \frac{RAD}{s}) + \frac{1}{2}(1s)(0.5\ \frac{RAD}{s})$

$= -1\ RAD + 0.25\ RAD$

$\Delta\theta = -0.75\ RAD$

(c) What is the angular displacement of the disk from **t** = 0 to **t** = 3 seconds?

O

→ SPEEDING UP

LOOK FOR |ω| ↓

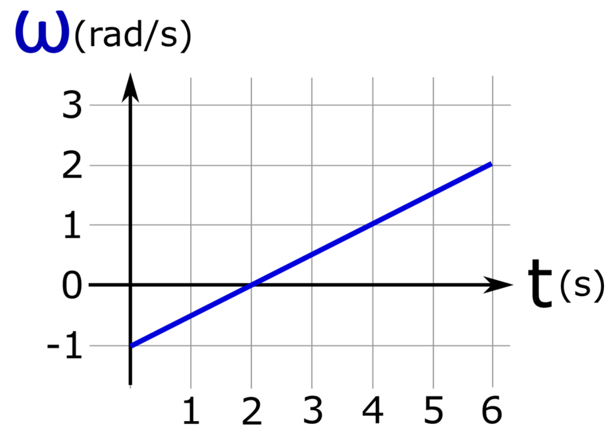
.... OR...

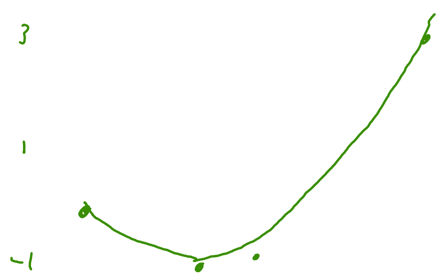
ω (-) + α(+)

(d) During which of the following time intervals is the disk slowing down?

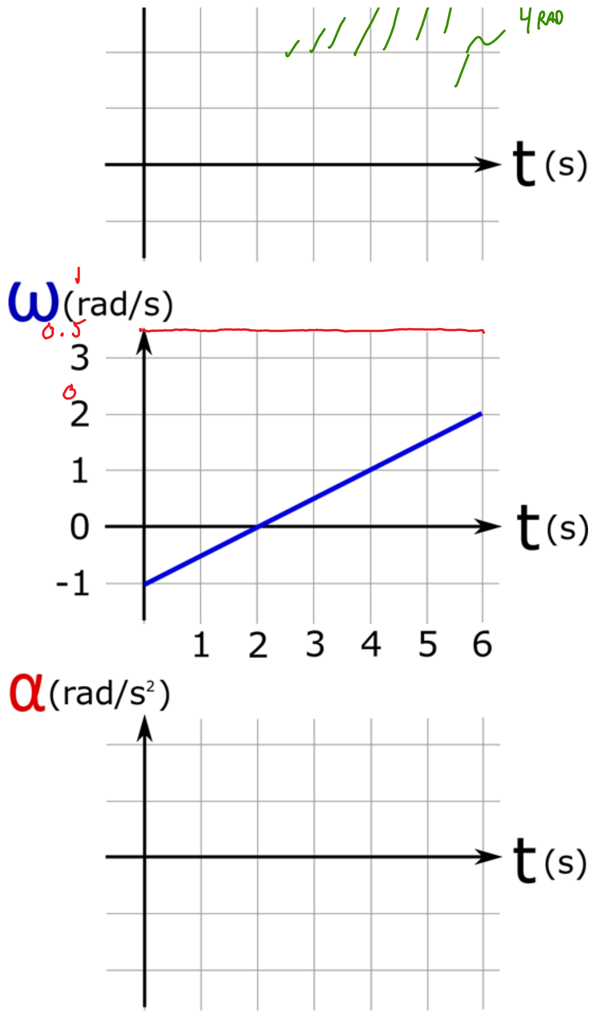
ω(+) + α(-)

(1) From **t** = 0 to **t** = 2 seconds.
(2) From **t** = 2 to **t** = 6 seconds.
(3) From **t** = 0 to **t** = 6 seconds.
(4) The slope is positive so the disk is never slowing down.





(e) Danny Johnson the DJ spins a disk whose angular velocity is plotted as a function of time as shown below. The disk initially started at **θ** = 0 radians. **Use the provided axes below to sketch the angular position and angular acceleration of the disk as functions of time.**



RK.2.L2-3:

Description: Given angular position vs time graph determine characteristics of angular velocity and acceleration at a given instant of time. (4 minutes)

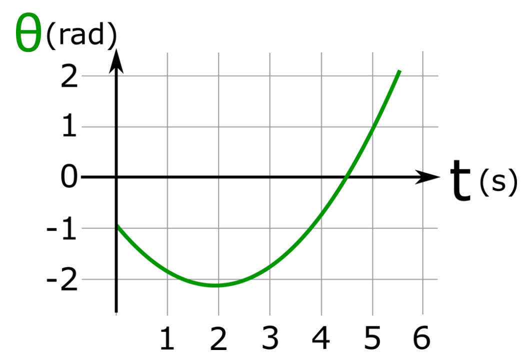
Learning Objectives: [1, 12, 13]

Problem Statement: Three students are discussing the graph shown below. Which of the following do you agree with the most?

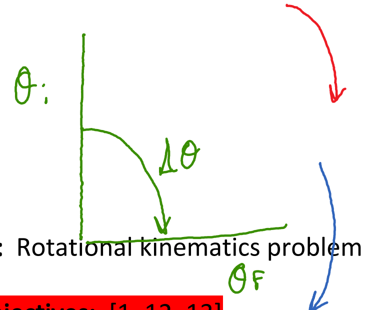
(1) At **t** = 3 seconds, the object is in the positive angular position region, moving towards the negative angular position region, and slowing down.

(2) At **t** = 3 seconds, the object is in the negative angular position region, moving towards the positive angular position region, and slowing down.

(3) At **t** = 3 seconds, the object is in the negative angular position region, moving towards the positive angular position region, and speeding up.



CCW(+)
CW(-)



Act II: Rotational kinematics

RK.2.L2-4:

$\omega_i = 0$ $\Delta\theta$

Description: Rotational kinematics problem solving for angular displacement. (6 minutes)

$\omega_f = 31.5 \frac{rad}{s}$

Learning Objectives: [1, 12, 13]

$\alpha = 12.6 \frac{rad}{s^2}$ Δt

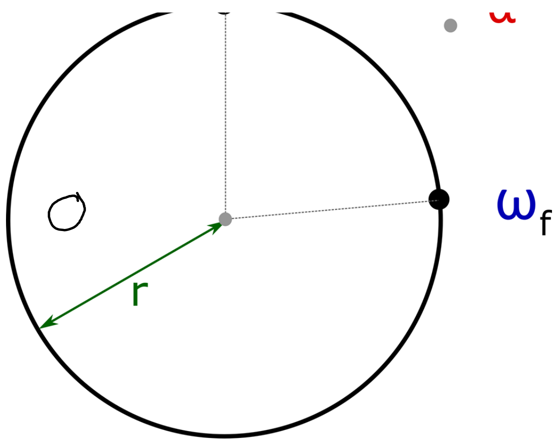
Problem Statement: A CD starts from rest and accelerates at a constant rate of 12.6 rad/s^2 until it reaches 31.5 rad/s. Through how many radians does the CD travel through from rest to 31.5 rad/s?

ω_i

$\Delta\theta$	ω_i	ω_f	α	Δt

$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

$\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha \Delta t^2$



$\omega_f^2 = 2\alpha\Delta\theta$

K	UK
$\Delta\theta = \frac{\omega_f^2}{2\alpha}$	$= \frac{(-31.5\ RAD/s)^2}{2(-12.6\ RAD/s^2)}$

$\omega_f = \omega_i + \alpha\Delta t$

$= -39.4\ RAD$

$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

(1) 0 rad.

(2) -1.25 rad.

(3) 2.5 rad.

(4) -39.4 rad.

(5) 397 rad

CCW(+)
CW(-)

$\omega_f = 0$

RK.2.L2-5:

Description: Rotational kinematics problem solving for angular displacement. (8 minutes)

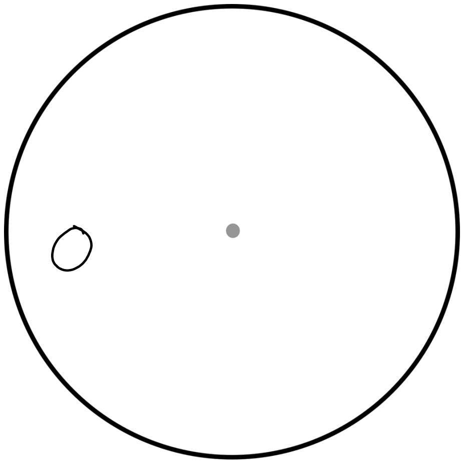
$\omega_f = 0$ $\Delta\theta$ ω_i

$\alpha = -19.8$ RA

Learning Objectives: [1, 12, 13]

Problem Statement: Boeing 737 planes typically use some variant of a CFM56 jet engine. An aircraft mechanic records the time, 45 seconds, it take the engine's core to come to rest after it's shut down. A sensor on the axel of the engine core is used to find the magnitude of average angular acceleration which was about 19.8 rad/s². Through how many radians did the jet engine core go through from idle speed to rest?

$\Delta t = 45$ sec



$\Delta\theta$	ω_i	ω_f	α	Δt
K		UK		

$\omega_f = \omega_i + \alpha \Delta t$

$0 = \omega_i + \alpha \Delta t$

$\omega_i = -\alpha \Delta t$

$= -(-19.8 \frac{rad}{s^2})(45 s)$

$\omega_i = 891 \frac{rad}{s}$

$\Delta\theta = \omega_i \Delta t + \frac{1}{2} \alpha \Delta t^2$

$= (891 \frac{rad}{s})(45 s) + \frac{1}{2}(-19.8 \frac{rad}{s^2})(45 s)^2$

$\Delta\theta = 20048$ rad

$\omega_f^2 = \omega_i^2 + 2 \alpha \Delta\theta$

(1) 891 rad.

(2) -19200 rad.

(3) 39600 rad.

(4) 20048 rad.

RADIANS ARE DIMENSIONLESS

Act III: Connecting linear and angular kinematic quantities

RK.2.L2-6:

Description: Units and dimensions of angular velocity. (2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Given that the tangential component of velocity is equal to the angular velocity times the radius, [Equation] , what are the dimensions of ω? The SI units of [Equation] are m/s , [Equation] has SI units of rad/s , and [Equation] has SI units of m.

(1) m/s

(2) [L]/[T]

(3) [Rad]/[T]

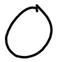
(4) 1/[T]

(5) [L]·[Rad]/[T]

~ HELIX

x ~ SPIRAL OUT

x ~ LINEAR MOTION



~ CIRCULAR

RK.2.L2-7:

Description: Choose the correct mathematical representation for velocity for non-UCM. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: We have already motivated why we use polar coordinates for an object moving in a circle. More generally, an object can move in a helix for which we would use cylindrical coordinates as follows: [Equation] . Which of the following velocity vectors could represent an object traveling in a circle while changing its speed?

(1) [Equation]

(2) [Equation]

(3) [Equation]

(4) [Equation]

$V_t = \omega r$ * SAME ω

SO $V_t \propto r$

L G

$V_t \propto r$ SO IF $r \to \frac{1}{2} r$

$V_t \to \frac{1}{2} V_t$

RK.2.L2-8:

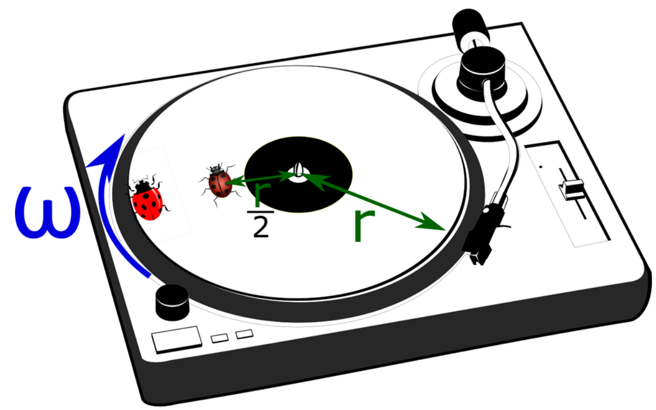
Description: Determine relationship between speed of two objects rotating at different radii. (2 minutes + 2 minutes + 3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A ladybug sits at the outer edge of a record player which is spinning clockwise, and a gentleman bug sits halfway between her and the axis of rotation. The record player makes 33 1/3 revolutions every 1 minute.

$a_r = \frac{v_t^2}{r}$ or $a_r = \omega^2 r$

$a_r \propto r$



(a) Is the gentleman bug's speed is _______________ the ladybug's speed.

(1) greater than
(2) less than
(3) equal to

(b) The gentleman bug's speed is _____________ the ladybug's speed.

(1) the same as
(2) one quarter of
(3) half of
(4) double
(5) quadruple

(c) The gentleman bug's radial component of acceleration is _____________ the ladybug's speed.

(1) the same as
(2) one quarter of
(3) half of
(4) double
(5) quadruple

$a_r = \frac{v_t^2}{r}$ or $a_r = \omega^2 r$

$= \left(3100 \frac{rad}{s}\right)^2 \left(91.9 \times 10^{-3} m\right)$

$a_r \approx 883000 \frac{m}{s^2}$

RK.2.L2-9:

Description: Calculate radial and tangential component of acceleration when given angular acceleration, angular velocity and radius. (2 minutes + 2 minutes + 2 minutes)

Learning Objectives: [1, 12, 13] $= \left(20 \frac{RAD}{s^2}\right)\left(91.9 \times 10^{-3} m\right)$

$a_t \simeq 1.84 \frac{m}{s^2}$

Problem Statement: A Beckman type 70 Ti centrifuge rotor is shown below. The Beckman ultracentrifuge that the rotor is in can accelerate the type 70 Ti rotor with an angular acceleration of 20 rad/s^2. After about 2.5 minutes, the rotor is spinning counter-clockwise at 3,100 rad/s.

(a) What is the radial component of acceleration at the tip of a tube in the type 70 rotor when it reaches 3,100 rad/s?

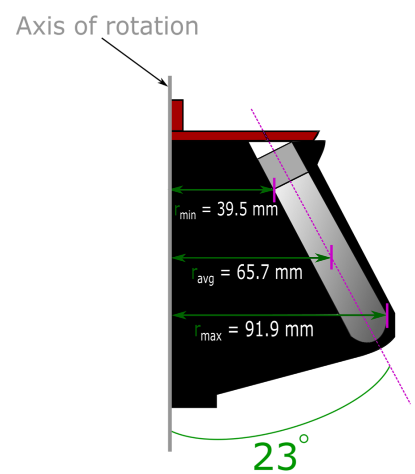
$\vec{a} = \langle a_r, a_t \rangle$

$\vec{a} = \langle 883000, 1.84 \rangle \, m/s^2$

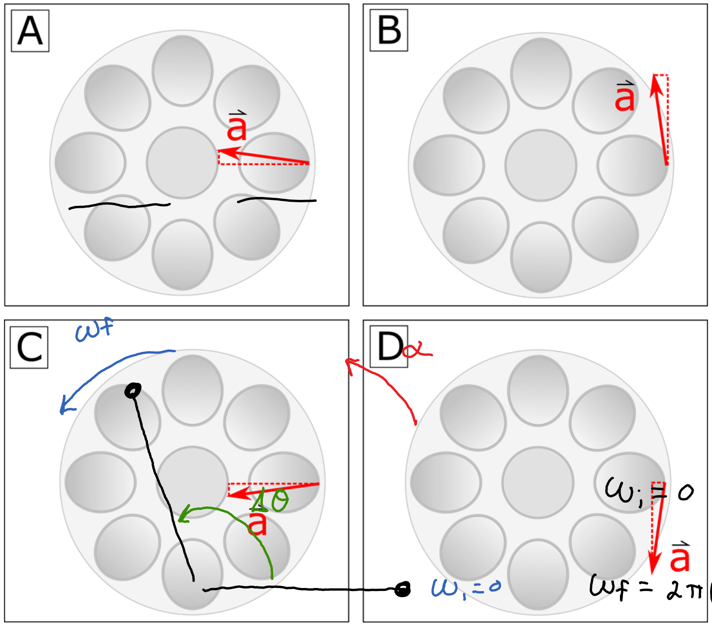
a_t

a_r

(b) What is the tangential component of acceleration at the tip of a tube in the type 70 rotor when it reaches 3,100 rad/s?



(c) Which of the following acceleration vectors correctly describes the acceleration of the tip of a tube in the type 70.1 Ti rotor when it reaches 3,100 rad/s? Recall the rotor is speeding up counter-clockwise.



SI] $12500 \frac{REV}{MIN} \times \frac{1\ MIN}{60\ SEC} = 208\ Hz$

$\Delta\theta$

α

$\Delta t = 50\ s$

RK.2.L2-10:

Description: Rotational kinematics problem solving for angular acceleration, linear distance, linear velocity, and linear acceleration. (4 minutes + 4 minutes + 3 minutes + 3 minutes)

$\omega_f = \omega_i + \alpha \Delta t$

$\alpha = \frac{\omega_f}{\Delta t} = \frac{2\pi(208\ Hz)}{50\ s} \approx 26.1\ \frac{RAD}{s^2}$

Learning Objectives: [1, 12, 13]

Problem Statement: The settings on a Beckman ultracentrifuge is set such that a type 70 Ti rotor starts from rest and uniformly speeds up to 12,500 RPM in 50 seconds.

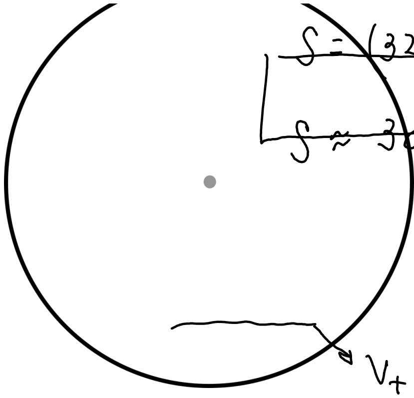
(a) What is the angular acceleration (in rad/s^2) of the rotor?

ARC LENGTH $\equiv S = \Delta\theta\, r$

$\Delta\theta$	ω_i	ω_f	α	Δt
K	UK			

$\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha\Delta t^2$

$\omega_f = \omega_i + \alpha\Delta t$



$$S = (32625 \text{ RAD})(91.9 \times 10^{-3} \text{ m})$$

$$S \approx 3000 \text{ m}$$

K	UK
	$\Delta\theta = \frac{1}{2}(26.1 \frac{\text{RAD}}{s^2})(50 s)^2$ $\Delta\theta \approx 32625$ RAD

$$\omega_f = \omega_i + \alpha \Delta t$$

$$\omega_f^2 = \omega_i^2 + 2 \alpha \Delta\theta$$

$$V_t = \omega r$$

$$= 2\pi (208 \text{ Hz})(91.4 \times 10^{-3} \text{ m})$$

$$V_t = 120 \text{ m/s}$$

(b) How far (in meters) does the tip of a tube in the rotor travel in the first 50 seconds?

$$\vec{a} = \langle a_r, a_t \rangle \qquad a_r = \omega^2 r \qquad a_t = \alpha r$$

$$a_r \approx 157000 \text{ m/s}^2 \qquad a_t \approx 2.40 \text{ m/s}^2$$

$$\vec{a} = \langle 157000, 2.40 \rangle \text{ m/s}^2$$

(c) What is the speed (in m/s) of the tip of a tube in the rotor at the 50 second mark?

(d) What is the linear acceleration vector of the tip of a tube in the rotor at the 50 second mark?

Conceptual questions for discussion

1. When using any of the three rotational kinematics equations, do you need to use radians for angular displacement, rad/s for angular velocity, and rad/s^2 for angular acceleration?
2. Describe a scenario where the angular position is positive but the angular velocity is negative.
3. Do you agree with the following statement: the area under an angular velocity vs time graph is the angular position?
4. Do you agree with the following statement: the area under an angular acceleration vs time graph is the angular velocity?
5. Sketch all three rotational kinematic quantity vs time graphs for the following scenario: A disk starts at 0 radians, begins to rotate CW slowly, then quickly speeds up in the CCW direction eventually going into the negative radian region.
6. Can a disk have a CCW angular acceleration and a CW angular velocity? If so, describe the motion of the disk as time progresses.
7. Two disks of radius **r** and **r**/2 are concentrically fused together and can freely rotate about their shared center as seen in the image below. Box **A** and box **B** hang from two strings lightly wrapped around each disk. When released from rest, the boxes will begin to fall downward and the strings do no slip relative to the disks they are wrapped around. Which of the following geometric constraints about the distances the boxes travel are?

   i. [Equation]

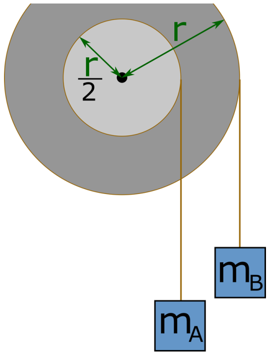
ii. [Equation]

iii. [Equation]

iv. [Equation]

v. [Equation]

vi. Cannot determine the constraint without knowing the mass of each box.



Hints

RK.2.L2-1: Is 1,500 RPM an angular velocity or frequency?

RK.2.L2-2: No hints.

RK.2.L2-3: No hints.

RK.2.L2-4: No hints.

RK.2.L2-5: Complete the physical representation first to get a better understanding of what is happening. Before doing algebra, use your known and unknown table to determine if there are enough equations with the number of unknowns you have to be able to solve for anything.

RK.2.L2-6: No hints.

RK.2.L2-7: No hints.

RK.2.L2-8: Think proportional reasoning.

RK.2.L2-9: No hints.

RK.2.L2-10: No hints.

(RK.L2.3) Practice Stage

Thursday, March 29, 2018 8:34 PM

Practice Stage: Xx

Post-lecture 2: Connecting Rotational and Translational Kinematics

Reading

1. none

Lecture Videos

1. none

Example Problems

1. none

Simulations

1. none

Other Suggested Content

1. none

Practice

1. none

Homework

RK.L2.3-01

Description: Lady bug and gentleman bug on a turntable

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: A lady bug (L) and gentleman bug (G), of equal mass, are both sitting on a turntable that is rotating at a constant rate, as shown in the figure. The ladybug is further from the axis of rotation.

(a) Which of the following statements are true regarding this situation?

(1) L and G both have the same speed
(2) L has a greater speed than G
(3) L has a smaller speed than G
(4) L and G both have the same angular velocity
(5) L has a greater angular velocity than G
(6) L has a smaller angular velocity than G
(7) L and G both have the same angular acceleration
(8) L has a greater angular acceleration than G
(9) L has a smaller angular acceleration than G

Answer: (2), (4), (7)

(b) Which of the following statements are true regarding this situation?

(1) L and G both have the same radial acceleration

(2) L has a greater radial acceleration than G
(3) L has a smaller radial acceleration than G
(4) L and G both have the same tangential acceleration
(5) L has a greater tangential acceleration as G
(6) L has a smaller tangential acceleration as G
(7) L and G both have the same net force acting on them
(8) L has a greater net force acting them than G
(9) L has a smaller net force acting on them than G

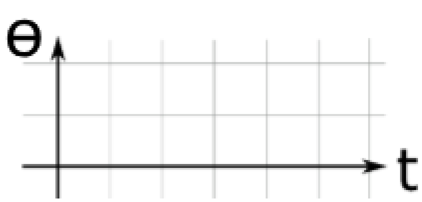
Answer: (2), (4), (8)

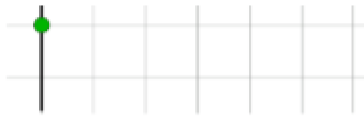
RK.L2.3-02

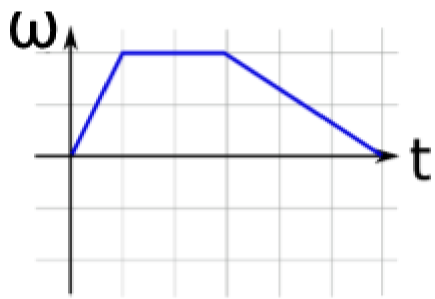
Description: Angular position, velocity, and acceleration graphical representation

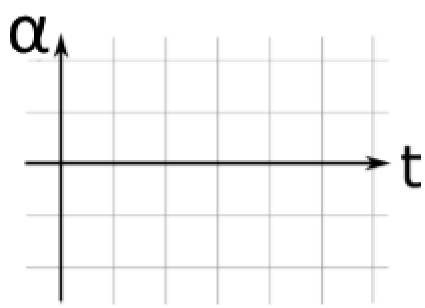
Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: The figure shows the angular velocity for a system as a function of time. Assume all the horizontal divisions are in seconds and all the vertical divisions are in rad/s. At t = 0 s the system is at a position of -1 rad.









(a) What is the angular acceleration in rad/s^2 at t = 4 s?

Answer: -0.667 rad/s^2

(b) What is the change in angular position between 0 and 2 s in radians?

Answer: 3 radians

(c) What is the final angular position, in degrees, after the entire 6 s interval?

Answer: 401°

(d) If the system has a radius of 40 cm, how fast is a point on the outermost edge moving at t = 1 s in m/s?

Answer: 0.80 m/s

(e) If the system has a radius of 40 cm, what is the tangential acceleration on a point on the outermost edge at t = 0.5 s in m/s^2?

Answer: 0.80 m/s^2

RK.L2.3-03

Description: Non-UCM kinematics of a car's crankshaft

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: The crankshaft (r = 3 cm) in a race car goes uniformly from rest to 3000 rpm in 2.0 s. How many revolutions does it make while reaching 3000 rpm?

(1) 10 revolutions
(2) 25 revolutions

(3) 42 revolutions
(4) 50 revolutions
(5) 63 revolutions
(6) 101 revolutions

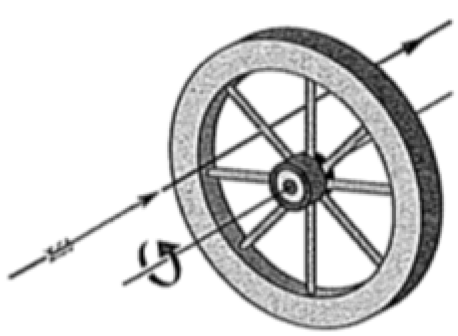
Answer: (4)

RK.L2.3-04

Description: Shooting an arrow through a wheel with spokes

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: The wheel in the figure has eight equally spaced spokes and a radius of 30 cm. It is mounted on a fixed axle and is spinning at 2.5 rev/s. You want to shoot a 20-cm-long arrow parallel to this axle and through the wheel without hitting any of the spokes. Assume that the arrow and spokes are very thin.



(a) What minimum speed must the arrow have?

(1) 1 m/s
(2) 2 m/s
(3) 3 m/s
(4) 4 m/s
(5) 5 m/s
(6) 6 m/s
(7) 7 m/s

Answer: (4) 4 m/s

(b) Does it matter where between the axle and the rim of the wheel you aim?
If so, what is the best location?

(1) Aim closest to the axle
(2) Aim closest to the rim
(3) Aim halfway between the axle and rim
(4) Doesn't matter where you aim assuming very thin arrow and spokes

Answer: (4)

RK.L2.3-05

Description: Rotational kinematics of an accelerating wheel

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: A 60 cm diameter wheel accelerates from rest at a rate of 7 rad/s^2.

(a) What is the tangential acceleration of a point on the edge of the wheel?

Answer: 4.2 m/s^2

(b) How long does it take for the wheel to turn through 14 rotations?

Answer: 5.01 s

(c) After the wheel has undergone 14 rotations, what is the radial component
of the acceleration on the edge the wheel?

Answer: 739 m/s^2

RK.L2.3-01

Description: How fast is Army the armadillo rolling down the hill

Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: The Brazilian three-banded armadillo has a hard outer exterior and rolls into a ball for protection. Suppose Army the armadillo rolls into a ball with a 5 cm radius. They are near a hill and begin to roll down it. After 15 s they have undergone 45.8 revolutions.

(a) What is Army's angular speed at this time?

(1) 12.7 rad/s
(2) 15.5 rad/s
(3) 22.0 rad/s
(4) 29.1 rad/s
(5) 38.4 rad/s

Answer: (5)

(b) How fast is Army travelling at this point?

(1) 1.92 m/s
(2) 2.23 m/s
(3) 3.49 m/s

(4) 4.24 m/s
(5) 5.56 m/s

Answer: (1)

RK.L2.3-0x

Description: One (or two) sentence quick description of the problem

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Write the problem statement here

Answer: x