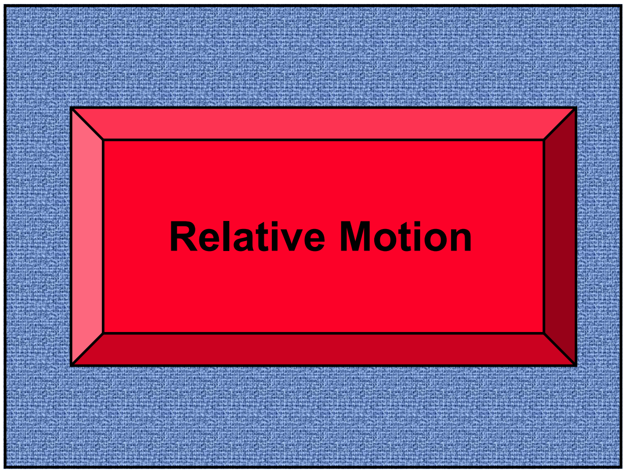
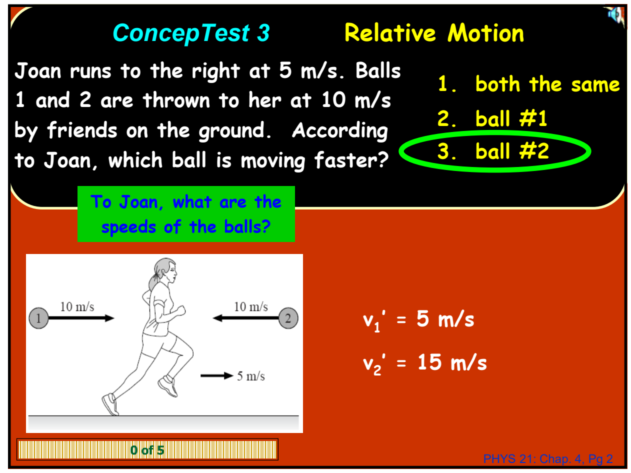
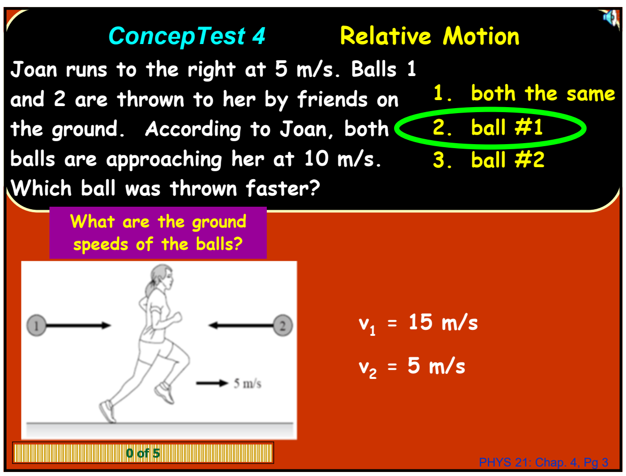

Relative Motion

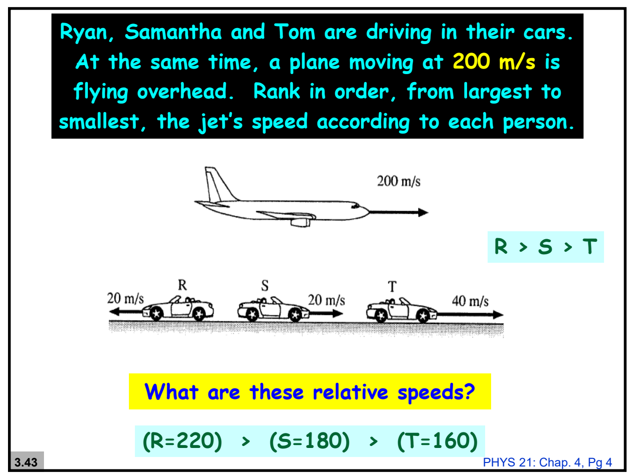
1


ConcepTest 3
Relative Motion
Joan runs to the right at 5 m/s. Balls 1 and 2 are thrown to her at 10 m/s by friends on the ground. According to Joan, which ball is moving faster?
1. both the same
2. ball #1
3. ball #2
To Joan, what are the speeds of the balls?
10 m/s
10 m/s
5 m/s
v1' = 5 m/s
v2' = 15 m/s
0 of 5
PHYS 21: Chap. 4, Pg 2

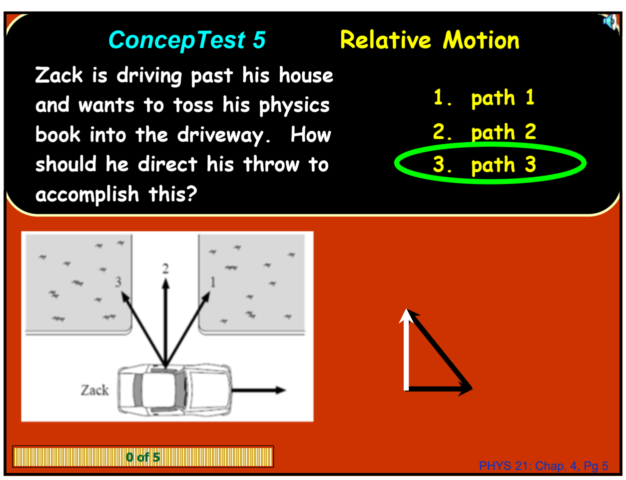
2


ConcepTest 4
Relative Motion
Joan runs to the right at 5 m/s. Balls 1 and 2 are thrown to her by friends on the ground. According to Joan, both balls are approaching her at 10 m/s. Which ball was thrown faster?
1. both the same
2. ball #1
3. ball #2
What are the ground speeds of the balls?
5 m/s
v1 = 15 m/s
v2 = 5 m/s
0 of 5
PHYS 21: Chap. 4, Pg 3

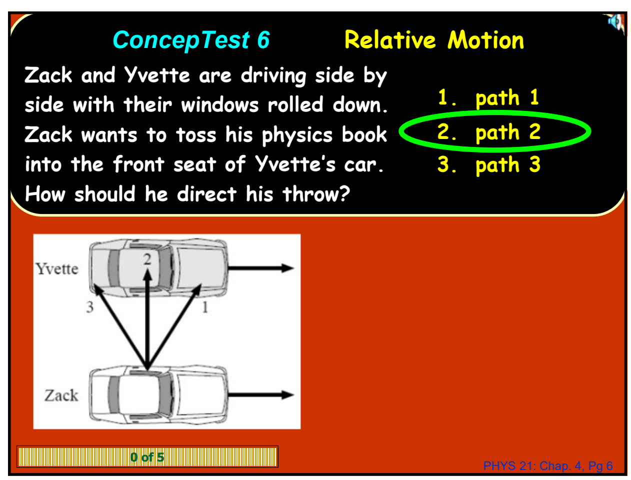
3


Ryan, Samantha and Tom are driving in their cars. At the same time, a plane moving at 200 m/s is flying overhead. Rank in order, from largest to smallest, the jet's speed according to each person.
200 m/s
R > S > T
20 m/s
R
S
20 m/s
T
40 m/s
What are these relative speeds?
(R=220) > (S=180) > (T=160)
3.43
PHYS 21: Chap. 4, Pg 4

4


ConcepTest 5
Relative Motion
Zack is driving past his house and wants to toss his physics book into the driveway. How should he direct his throw to accomplish this?
1. path 1
2. path 2
3. path 3
Zack
0 of 5
PHYS 21: Chap. 4, Pg 5

5

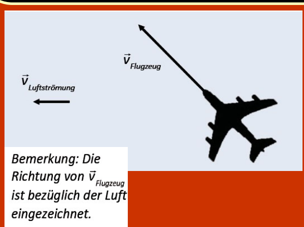

ConcepTest 6
Relative Motion
Zack and Yvette are driving side by side with their windows rolled down. Zack wants to toss his physics book into the front seat of Yvette's car. How should he direct his throw?
1. path 1
2. path 2
3. path 3
Yvette
Zack
0 of 5
PHYS 21: Chap. 4, Pg 6

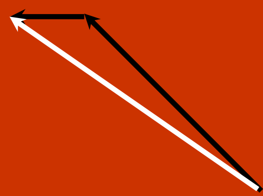
6

ConcepTest 8 — Relative Motion

A jet has an airspeed of 980 km/hr and it flies in a wind of 120 km/hr in a different direction. What is the ground speed of the plane?

1. v = 120
2. 120 < v < 980
3. v = 980
4. 980 < v < 1100
5. v = 1100





0 of 5

7

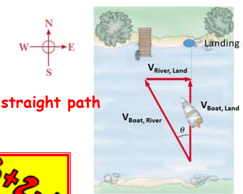
A kayaker wants to paddle north across a 100 m wide river.
The current in the river is flowing to the east at 2 m/s.
The kayaker can paddle in still water at a speed of 3 m/s.

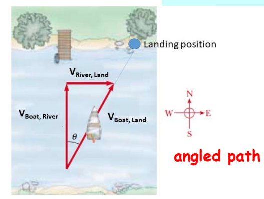
In which direction should the kayaker paddle in order to travel straight across the river?

θ = 41.8°

How long will it take the kayaker to cross the river?

t = 44.6 s





3+2:5 4.53

8

A kayaker wants to paddle north across a 100 m wide river.
The current in the river is flowing to the east at 2 m/s.
The kayaker can paddle in still water at a speed of 3 m/s.

In which direction should the kayaker paddle in order to travel straight across the river?

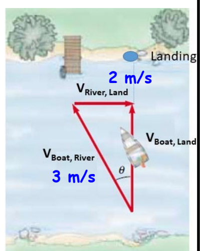
How long will it take the kayaker to cross the river?

SOLUTION

$$\sin\theta = \frac{2}{3} \Rightarrow \theta = 41.8°$$

$$v_{boat,land} = 3\cos\theta = 2.24\ \frac{m}{s}$$

$$t = \frac{\Delta x}{v} = \frac{100\ m}{2.24\ \frac{m}{s}} = 44.6\ s$$



9

ConcepTest 5 — John and Mary

Working by himself, John can paint a bedroom in a half hour. For Mary alone, it takes one hour to paint the bedroom. If John and Mary work together, how long would it take?

1. 1½ hrs
2. 15 minutes
3. 45 minutes
4. 20 minutes
5. 24¼ minutes

0 of 5

10

When the moving sidewalk at Dulles Airport is broken, it takes you 50 s to walk from the gate to baggage claim. When it is working and you stand still on the moving sidewalk, it takes 75 s to travel the same distance.

How long will it take you if you walk while riding on the moving sidewalk?

t = 30 s

3+2:5 4.16

11

When the moving sidewalk at Dulles Airport is broken, it takes you 50 s to walk from the gate to baggage claim. When it is working and you stand still on the moving sidewalk, it takes 75 s to travel the same distance.

t = 30 s

How long will it take you if you walk while riding on the moving sidewalk?

SOLUTION

$$v_{walk} = \frac{dist}{time} = \frac{L}{50\ s} \qquad v_{moving} = \frac{dist}{time} = \frac{L}{75\ s}$$

$$v_{walk+moving} = v_{walk} + v_{moving} = \frac{L}{50} + \frac{L}{75} = \frac{5L}{150} = \frac{L}{30}$$

$$t = \frac{L}{v} = \frac{L}{L/30} = 30\ s$$

12

Uniform Circular Motion

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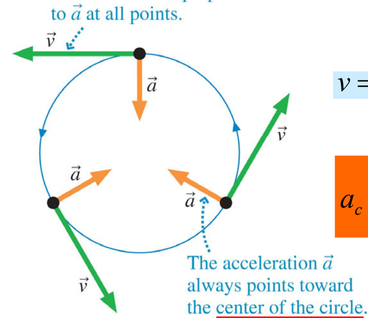
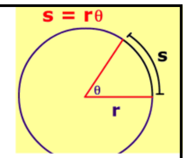
Circular Motion

The velocity $\vec{v}$ is always tangent to the circle and perpendicular to $\vec{a}$ at all points.





$v = r\omega$

(m/s) linear velocity v

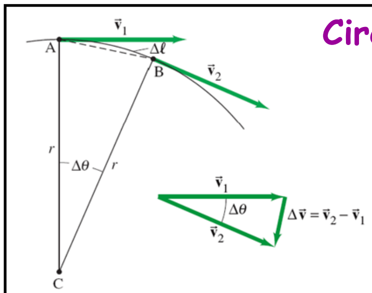
angular velocity ω (rad/s)

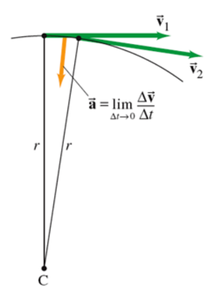
$$a_c = \frac{v^2}{r} = r\omega^2$$

centripetal accel. a_c

14

Circular Motion

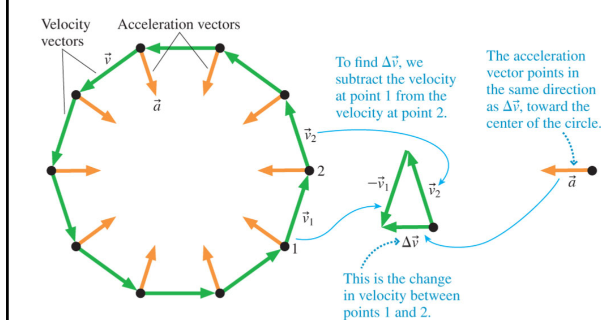




$$a_c = \frac{v^2}{r} = r\omega^2$$

15

KEY CONCEPT FIGURE 3.33 Motion diagram for uniform circular motion.



$$a_c = \frac{v^2}{r} = r\omega^2$$

PHYS 21: Chap. 4, Pg 16

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Circular Motion

Frequency f and period T: $f = \frac{1}{T}$ or $T = \frac{1}{f}$

Frequency is related to angular velocity:

$$\omega = 2\pi f$$

where

ω = angular velocity, in radians per second

2π = the number of radians in one cycle

f = the number of cycles per second (frequency)

PHYS 21: Chap. 4, Pg 17

17

Kinematics Equations

for linear and circular motion

Translational	Rotational
$v = v_0 + at$	$\omega = \omega_0 + \alpha t$
$\Delta x = v_0 t + \frac{1}{2}at^2$	$\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$
$v^2 = v_0^2 + 2a\Delta x$	$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

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

angular acceleration: $\alpha = \frac{\Delta\omega}{\Delta t}$

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SYNTHESIS 7.1 Linear and circular motion

The variables and equations for linear motion have analogs for circular motion.

		Linear motion	Circular motion	
Variables	Position (m)	x	θ	Angle (rad)
	Velocity (m/s)	$v_x = \frac{\Delta x}{\Delta t}$	$\omega = \frac{\Delta\theta}{\Delta t}$	Angular velocity (rad/s)
	Acceleration (m/s^2)	$a_x = \frac{\Delta v_x}{\Delta t}$	$\alpha = \frac{\Delta\omega}{\Delta t}$	Angular acceleration (rad/s^2)
Equations	Constant velocity	$\Delta x = v\Delta t$	$\Delta\theta = \omega\Delta t$	Constant angular velocity
	Constant acceleration	$\Delta v = a\Delta t$	$\Delta\omega = \alpha\Delta t$	Constant angular acceleration
		$\Delta x = v\Delta t + \frac{1}{2}a(\Delta t)^2$	$\Delta\theta = \omega_i\Delta t + \frac{1}{2}\alpha(\Delta t)^2$	

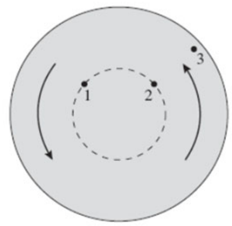
PHYS 21: Chap. 4, Pg 19

19

There are 3 points shown on a steadily rotating wheel.

a) Rank in order, from largest to smallest, the angular velocities of the three points. $\omega_1 = \omega_2 = \omega_3$

b) Rank in order, from largest to smallest, the linear speeds of the three points. $v_3 > (v_1 = v_2)$

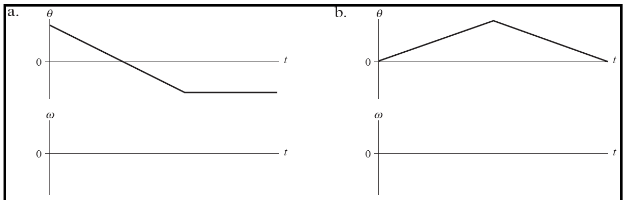


$v = r\omega$

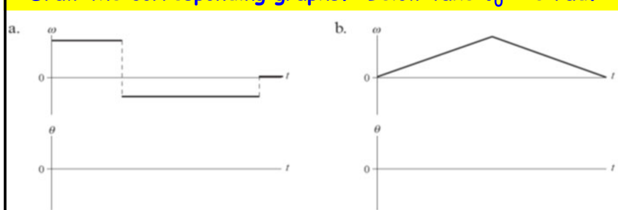
linear velocity v
angular velocity ω

6.2 PHYS 21: Chap. 4, Pg 20

20

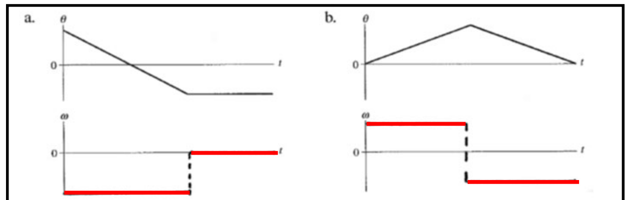


Draw the corresponding graphs. Below take θ_0 = 0 rad.

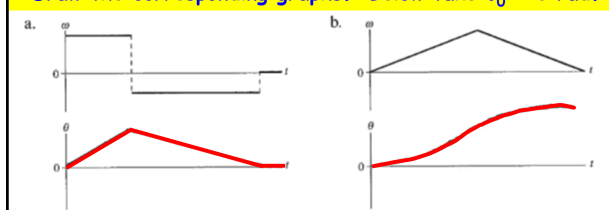


4.21-4.22 PHYS 21: Chap. 4, Pg 21

21



Draw the corresponding graphs. Below take θ_0 = 0 rad.

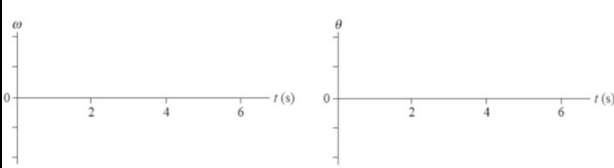


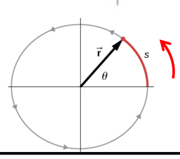
4.21-4.22 PHYS 21: Chap. 4, Pg 22

22

A particle in circular motion rotates CW at angular speed 4 rad/s for 2 s, then rotates CCW at 2 rad/s for 4 s.

Graph the angular velocity and the angular position. (take θ_0 = 0 rad).





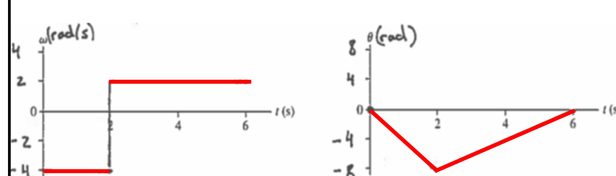
CCW = positive
CW = negative

4.23 PHYS 21: Chap. 4, Pg 23

23

A particle in circular motion rotates CW at angular speed 4 rad/s for 2 s, then rotates CCW at 2 rad/s for 4 s.

Graph the angular velocity and the angular position. (take θ_0 = 0 rad).



4.23 PHYS 21: Chap. 4, Pg 24

24

A particle rotates in a circle at a given radius with centripetal acceleration a_c = 8 m/s^2.
How does a_c change under the following conditions?

1) radius doubles without changing angular velocity

2) radius doubles without changing particle's speed

3) angular velocity doubles without changing circle's radius

4) period doubles without changing circle's radius

4.24 PHYS 21: Chap. 4, Pg 25

25

ConcepTest 6 Circular Motion

A particle rotates in a circle at a given radius with centripetal acceleration of a_c = 8 m/s^2. How does a_c change if the radius doubles without changing the angular velocity?

1. a_c = 2
2. a_c = 4
3. a_c = 8
4. a_c = 16
5. a_c = 32

$$a_c = \frac{v^2}{r} = r\omega^2$$

0 of 5

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ConcepTest 7 Circular Motion

A particle rotates in a circle at a given radius with centripetal acceleration of a_c = 8 m/s^2. How does a_c change if the radius doubles without changing the linear speed of the particle?

1. a_c = 2
2. a_c = 4
3. a_c = 8
4. a_c = 16
5. a_c = 32

$$a_c = \frac{v^2}{r} = r\omega^2$$

0 of 5

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ConcepTest 8 Circular Motion

A particle rotates in a circle at a given radius with centripetal acceleration of a_c = 8 m/s^2. How does a_c change if the angular velocity doubles without changing the radius of the motion?

1. a_c = 2
2. a_c = 4
3. a_c = 8
4. a_c = 16
5. a_c = 32

$$a_c = \frac{v^2}{r} = r\omega^2$$

0 of 5

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ConcepTest 9 Circular Motion

A particle rotates in a circle at a given radius with centripetal acceleration of a_c = 8 m/s^2. How does a_c change if the period doubles without changing the radius of the motion?

1. a_c = 2
2. a_c = 4
3. a_c = 8
4. a_c = 16
5. a_c = 32

$$a_c = \frac{v^2}{r} = r\omega^2$$

0 of 5

29

"Did you know that the earth spins at 1038 mph?"

What is the tangential speed of a person on the equator?

(R_{Earth} = 6370 km)

1 mile = 1.61 km

v = 1668 km/hr
= 463 m/s
= 0.288 mi/s
= 1036 mi/hr

PHYS 21:

30

A well-lubricated bicycle wheel can spin for a long time before stopping. Consider a wheel that is initially rotating at 100 rpm. With a constant angular acceleration slowing the wheel, it takes 60 s for the wheel to stop completely.

How many revolutions does it make while stopping?

50 revs

What is the tangential speed of a person on the equator? (the radius of the Earth is 6370 km)

4.64