

Physics 100A Homework 9 – Chapter 10 (part 1)

10.1) The following angles are given in degrees. Convert them to radians.

1. **Picture the Problem:** This is a units conversion problem.

Strategy: Multiply the angle in degrees by $\left(\frac{\pi \text{ radians}}{180^\circ}\right)$ to get radians.

Solution: $30^\circ \left(\frac{\pi \text{ rad}}{180^\circ}\right) = \boxed{\frac{\pi}{6} \text{ rad}}$ $45^\circ \left(\frac{\pi \text{ rad}}{180^\circ}\right) = \boxed{\frac{\pi}{4} \text{ rad}}$ $90^\circ \left(\frac{\pi \text{ rad}}{180^\circ}\right) = \boxed{\frac{\pi}{2} \text{ rad}}$ $180^\circ \left(\frac{\pi \text{ rad}}{180^\circ}\right) = \boxed{\pi \text{ rad}}$

Insight: The quantity π is the circumference of a circle divided by its diameter. $\pi = 3.1415926536 \dots$

10.6) A spot of paint on a bicycle tire moves in a circular path of radius 0.33 m.

6. **Picture the Problem:** The tire rotates about its axis through a certain angle.

Strategy: Use equation 10-2 to find the angular displacement.

Solution: Solve equation 10-2 for θ :
$$\theta = \frac{s}{r} = \frac{1.95 \text{ m}}{0.33 \text{ m}} = \boxed{5.9 \text{ rad}}$$

$$\theta = (5.9 \text{ rad}) \left(\frac{180^\circ}{\pi \text{ rad}}\right) = 338^\circ$$

Insight: This angular distance corresponds to 338° or 94% of a complete revolution.

Angular Motion with Constant Acceleration

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2 \quad (\text{equation 1})$$

$$\omega = \omega_0 + \alpha t \quad (\text{equation 2})$$

- A) θ is a function of time.
- B) θ_0 is **not** a function of time.
- C) ω_0 is not a function of time.
- D) ω is a function of time.
- E) The following equation is not an explicit function of time.

$$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0) \quad (\text{equation 3})$$

- F) In $(\omega = \omega_0 + \alpha t)$, t is the time elapsed from when the angular velocity equals ω_0 until the angular velocity equals ω .
- G) In order to find t directly from the 3 kinematic equations is necessary to have three pieces of information. Only knowing the final angular velocity is not enough.
- H) You are now given an additional piece of information: It takes five complete revolutions for the turntable to speed up from 33 1/3 rpm to 45 rpm. Which of the following equations could you use to directly solve for the numerical value of the angular acceleration α ?

Now we have three pieces of information: angle, final angular velocity, initial angular velocity. To get the angular acceleration directly we can use equation 3.

Constant Angular Acceleration in the Kitchen

Dario, a prep cook at an Italian restaurant, spins a salad spinner 20.0 times in 5.00 seconds and then stops spinning it. The salad spinner rotates 6.00 more times before it comes to rest. Assume that the spinner slows down with constant angular acceleration.

A) What is the angular acceleration of the salad spinner as it slows down?

The problem can be divided in two parts:

Part 1: Spinning to build up to what will be the initial angular velocity.

Each spin is a revolution or turn.

$$\theta = (20\text{rev})(2\pi\text{rad/rev}) = 40\pi\text{rad}$$

$$\omega_0 = \frac{\theta}{t} = \frac{40\pi}{5.00} = 25.1 \text{ rad/s}$$

Part 2: After having started with the angular velocity calculated from part 1, the spinner makes 6 turns more before coming to rest.

$$\theta = (6)(2\pi) = 37.7 \text{ rad}$$

$$\omega = 0$$

From equation 3:

$$\alpha = -\frac{\omega_0^2}{2\theta} = -\frac{(25.1)^2}{2(37.7)} = -8.38 \text{ rad/s}^2$$

$$\alpha = -(8.38 \text{ rad/s}^2) (180^\circ / \text{rad}) = -480^\circ / \text{s}^2$$

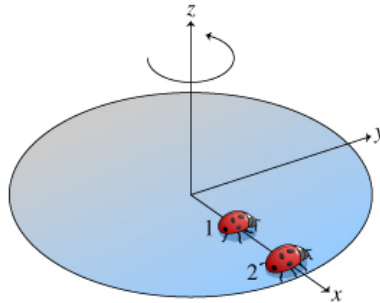
B) What is the time?

From equation 2:

$$t = -\frac{\omega_0}{\alpha} = -\frac{25.1}{-8.38} = 3.0 \text{ s}$$

Lady Bugs in a Rotating Disk

Two ladybugs sit on a rotating disk, as shown in the figure (the ladybugs are at rest with respect to the surface of the disk and do not slip). Ladybug 1 is halfway between ladybug 2 and the axis of rotation.



A) The angular speed is the same for both lady bugs.

B) Linear or tangential speed:

$$v = r\omega$$

$$\frac{v_1}{v_2} = \frac{r_1\omega}{r_2\omega} = \frac{r_1}{2r_1} = \frac{1}{2}$$

C) The radial acceleration:

$$a_c = r\omega^2, \quad \text{then}$$

$$\frac{a_{cp,2}}{a_{cp,1}} = \frac{1}{2}$$

D) Since the disk is rotating counterclockwise the direction of the angular velocity is out of the plane or in the \hat{z} direction.

E) Now assume that at the moment pictured in the figure, the disk is rotating but slowing down. Each ladybug remains "stuck" in its position on the disk. What is the direction of the *tangential* component of the acceleration (i.e., acceleration tangent to the trajectory) of ladybug 2?

At the instant shown $\$v\$$ is in the positive y-direction. So if the disk is slowing down, the tangential acceleration at the moment shown is in the negative y-direction

Marching Band

A marching band consists of rows of musicians walking in straight, even lines. When a marching band performs in an event, such as a parade, and must round a curve in the road, the musician on the outside of the curve must walk around the curve in the same amount of time as the musician on the inside of the curve. This motion can be approximated by a disk rotating at a constant rate about an axis perpendicular to its plane. In this case, the axis of rotation is at the inside of the curve.

Consider two musicians, Alf and Beth. Beth is four times the distance from the inside of the curve as Alf.

A) If Beth travels a distance s during time Δt , how far does Alf travel during the same amount of time?

In a certain time Δt both musicians travel the same angle θ . Since $s = r\theta$, the arc covered by Beth is four times the arc covered by Alf.

B) If Alf moves with speed v , Beth's speed is $4v$.

10.27) Two children, Jason and Betsy, ride on the same merry-go-round. Jason is a distance R from the axis of rotation; Betsy is a distance $2R$ from the axis.

A) Is the rotational period of Jason greater than, less than, or equal to the rotational period of Betsy?

$$T = \frac{2\pi}{\omega}$$

As we have discussed the angular speed is the same for all points in a rotating disk, irrelevant of the radial distance from the rotation axis. Then the period is also the same. A more elaborate explanation below.

27. **Picture the Problem:** Jason is a distance R from the axis of rotation of a merry-go-round and Betsy is a distance $2R$ from the axis.

Strategy: Use an understanding of rotational motion to answer the conceptual question.

Solution: 1. (a) Although the linear speeds of Jason and Betsy are different, their angular speeds are the same because they both ride on the same merry-go-round. Because each completes one revolution in the same amount of time, the rotational period of Jason is **equal to** the rotational period of Betsy.

2. (b) The best explanation is **III**. It takes the same amount of time for the merry-go-round to complete a revolution for all points on the merry-go-round. Statements I and II are each false.

Insight: Jason has a smaller linear speed $v_t = r\omega$ and a smaller centripetal acceleration $a_{cp} = r\omega^2$ than does Betsy.

10.34) Jeff of the Jungle swings on a vine that is 7.20 m long. At the bottom of the swing, just before hitting the tree, Jeff's linear speed is 8.50 m/s.

A) Find Jeff's angular speed at this time.

B) What centripetal acceleration does Jeff experience at the bottom of his swing?

C) What exerts the force that is responsible for Jeff's centripetal acceleration?

34. **Picture the Problem:** Jeff clings to a vine and swings along a vertical arc as depicted in the figure at right.

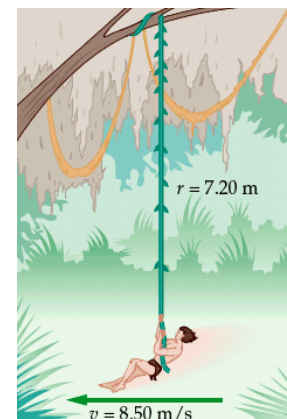
Strategy: Use equation 10-12 to find the angular speed from the knowledge of the linear speed and the radius. Use equation 6-15 to find the centripetal acceleration from the speed and the radius of motion.

Solution: 1. (a) Solve equation 10-12 for ω :

$$\omega = \frac{v_t}{r} = \frac{8.50 \text{ m/s}}{7.20 \text{ m}} = \boxed{1.18 \text{ rad/s}}$$

2. (b) Apply equation 6-15 directly:

$$a_{cp} = \frac{v_t^2}{r} = \frac{(8.50 \text{ m/s})^2}{7.20 \text{ m}} = \boxed{10.0 \text{ m/s}^2}$$



3. (c) The centripetal force required to keep Jeff moving in a circle is the tension in the vine.

Insight: The vine must actually do two things, support Jeff's weight and provide his centripetal force. That is why it is possible that the vine is strong enough to support him when he is hanging vertically but not strong enough to support him while he is swinging. There's no easy way for him to find out without trying... but he should wear a helmet!

10.39) A Ferris wheel with a radius of 9.5 m rotates at a constant rate, completing one revolution every 36 s.

39. **Picture the Problem:** The Ferris wheel rotates at a constant rate, with the centripetal acceleration of the passengers always pointing toward the axis of rotation. The acceleration of the passenger is thus upward when they are at the bottom of the wheel and downward when they are at the top of the wheel.

Strategy: Use equation 10-13 to find the centripetal acceleration. The centripetal acceleration remains constant (as long as the angular speed remains the same) and points toward the axis of rotation.

Solution: 1. (a) Apply equation 10-13 directly:
$$a_{\text{cp}} = r\omega^2 = (9.5 \text{ m}) \left(\frac{2\pi \text{ rad}}{36 \text{ s}} \right)^2 = \boxed{0.29 \text{ m/s}^2}$$

2. When the passenger is at the top of the Ferris wheel, the centripetal acceleration points downward toward the axis of rotation.

3. (b) The centripetal acceleration remains 0.29 m/s^2 for a passenger at the bottom of the wheel because the radius and angular speed remain the same, but here the acceleration points upward toward the axis of rotation.

Insight: In order to double the centripetal acceleration you need to increase the angular speed by a factor of $\sqrt{2}$ or decrease the period by a factor of $\sqrt{2}$. In this case a period of 25 seconds will double the centripetal acceleration.