Angular Acceleration, Radial Acceleration

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1. Problems:

1. A wheel speeds up to 30 rad/s from rest in 5 seconds. What is the average angular acceleration of the wheel?

Solution: $\omega_0 = 0$ rad/s $\quad \omega_f = 30$ rad/s $\quad t = 5$ seconds

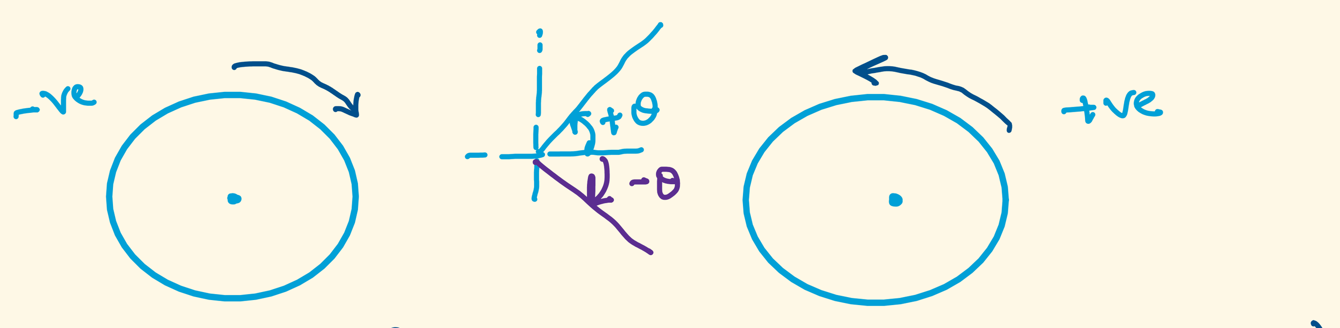
$$\bar{\alpha} = \frac{\omega_f - \omega_0}{t} = \frac{30-0}{5} = 6 \text{ rad/s}^2$$

2. A disc slows down from 85 rad/s to 25 rad/s in 4 seconds. What is the average angular acceleration of the disc?

Solution: $\bar{\alpha} = \frac{\omega_f - \omega_0}{t} = \frac{25-85}{4} = \frac{-60}{4}$

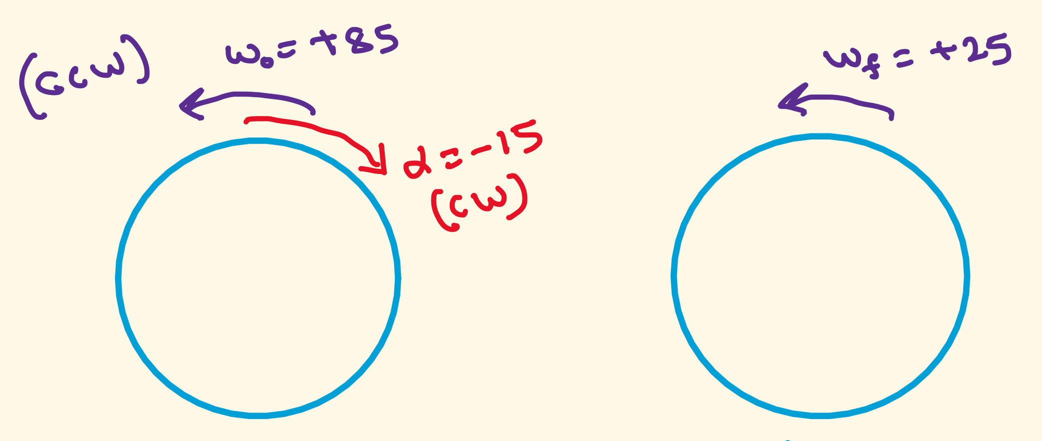
$$= -15 \text{ rad/s}^2$$

Note: What does −ve sign mean? Can angular velocities be negative too?



Clockwise (CW) Counter-Clockwise (CCW)

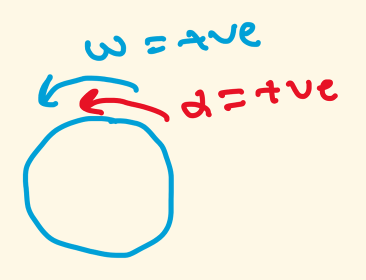
Let's visualize the scenario from our question:



Because of $\alpha = -15$ (clockwise), the angular velocity reduced from +85 to +25, but at this moment it is still in counter-clockwise direction but eventually it will go to clockwise because of −ve α.

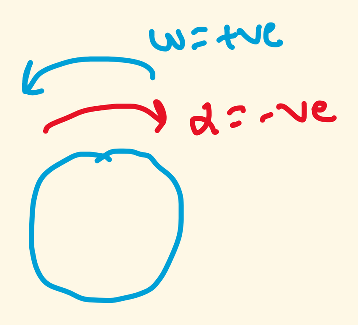
→ **KEYPOINTS**

- **Case-01:**



in this case, disc will speed up faster and faster.

- **Case-02:**



in this case, the disc will slow down.

3. A disk with a diameter of 30 cm spins at a constant rate of 40 rad/s.
(a) What is the linear velocity of a point at the edge of the disk?
(b) What is the radial acceleration of the disk?

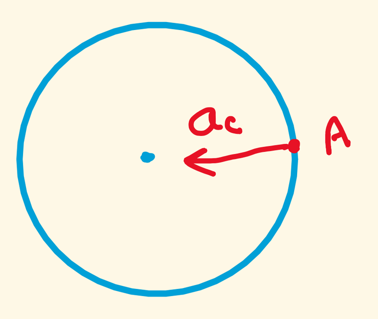
Solution:

$$R = \frac{30 \text{ cm}}{2} = \frac{30}{2 \times 100} \text{ m} = \frac{3}{20} \text{ m}$$

(a) $\alpha = 0$ [$\because$ constant angular velocity]
$\omega_f = \omega_0 = 40$ rad/s

$\therefore \ v = \omega \cdot R$
$= 40 \cdot \frac{3}{20}$ m/s
$= 6$ m/s

(b) Radial Acceleration means the Centripetal Acceleration



Radial Acceleration $= a_c$
$= \frac{v^2}{R}$
$= \frac{6 \times 6}{3/20}$ m/s^2
$= 2 \times 6 \times 20$ m/s^2
$= 240$ m/s^2

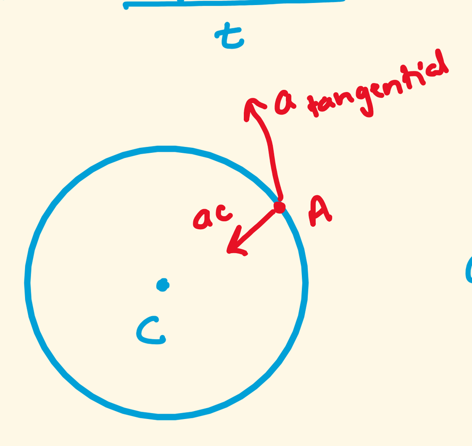
4. A disk with a radius of 1.5 cm speeds up from 20 rad/s to 100 rad/s in 20 seconds.
(a) What is the average angular acceleration of the disk.
(b) What is the centripetal acceleration of a point at the edge of the disk when the angular speed is 60 rad/s?
(c) What is the net acceleration of the point in part (b)?

Solution: $R = 1.5 \text{ cm} = \frac{1.5}{100} \text{ m} = \frac{15}{1000} \text{ m}$

(a) $\omega_f = 100$ rad/s $\quad \omega_0 = 20$ rad/s $\quad t = 20$ sec

$$\bar{\alpha} = \frac{\omega_f - \omega_0}{t} = \frac{100-20}{2} = 40 \text{ rad/s}^2$$

(b)



$a_c = \frac{v^2}{R} = \omega^2 R$
$= (60)^2 \cdot \frac{15}{1000}$
$= 36\cancel{00} \cdot \frac{15}{10\cancel{00}}$
$= 54$ m/s^2

(c) $a_{tangential} = \alpha \cdot R$
$= (4\cancel{0}) \cdot \frac{\cancel{15}\,3}{\cancel{1000}\ \cancel{20}\ 5}$

$= \frac{3}{5} = 0.6$ m/s^2

$\therefore \ a_{net} = \sqrt{a_c^2 + a_{tangential}^2}$
$= \sqrt{(54)^2 + (0.6)^2}$
$= \sqrt{2916 + 0.36}$
≈ 54.003 m/s^2

NOTE: If we increase the angular velocity of disc 2 times, what will be the effect on centripetal acceleration?

Solution: $a_c = \omega^2 R$
Now, $\omega_{new} = 2\omega$

$\therefore (a_c)_{new} = \omega_{new}^2 R$
$= (2\omega)^2 R$
$= 4\omega^2 R$
$= 4 (a_c)$

Therefore, the new centripetal acceleration will become 4 times to its original value.

2. References:

1. The Organic Chemistry Tutor

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