EOT – Grade 11 Adv Plan C

Ms. Asmaa Alhameed

2023-2024

MCQ

Question 1-7, 13, 14
as per the EOT

(1) Define the center of mass as the point at which all the mass of an object appears to be concentrated. (2) Recall that center of gravity is equivalent to center of mass in situations where the gravitational force is constant everywhere throughout the object.	Student Book (S.B)	226

Definition

The **center of mass** is the point at which we can imagine all the mass of an object to be concentrated.

Thus, the center of mass is also the point at which we can imagine the force of gravity acting on the entire object to be concentrated. If we can imagine all of the mass to be concentrated at this point when calculating the force due to gravity, it is legitimate to call this point the *center of gravity*, a term that can often be used interchangeably with *center of mass*. (To be precise, we should note that these two terms are only equivalent in situations where the gravitational force is constant everywhere throughout the object. In Chapter 12, we will see that this is not the case for very large objects.)

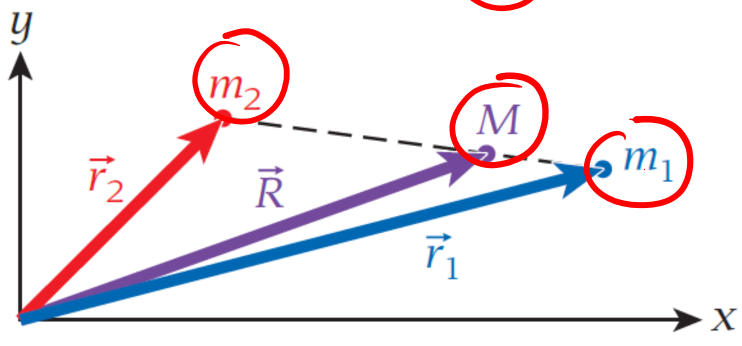
2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure **8.2** Concept Check **8.1**	**227**

$$\vec{R} = \frac{\vec{r}_1 m_1 + \vec{r}_2 m_2}{m_1 + m_2}.$$

→ vector

$$X = \frac{x_1 m_1 + x_2 m_2}{m_1 + m_2}, \quad Y = \frac{y_1 m_1 + y_2 m_2}{m_1 + m_2}, \quad Z = \frac{z_1 m_1 + z_2 m_2}{m_1 + m_2}.$$

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure 8.2 Concept Check 8.1	227



$m_1 > m_2$

FIGURE 8.2 Location of the center of mass for a system of two masses m_1 and m_2, where $M = m_1 + m_2$.

Concept Check 8.1

In the case shown in Figure 8.2, what are the relative magnitudes of the two masses m_1 and m_2?

a) $m_1 < m_2$

b) $m_1 > m_2$

c) $m_1 = m_2$

d) Based solely on the information given in the figure, it is not possible to decide which of the two masses is larger.

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure 8.2 Concept Check 8.1	227

سؤال وزاري سابق

"A Point where all weight of object acts", what is this point called?

"نقطة على الجسم ترتكز فيها كتلة هذا الجسم كلها"، ماذا تسمى هذه النقطة؟

center of mass
مركز الكتلة

center of field
مركز المجال

central point
النقطة المركزية

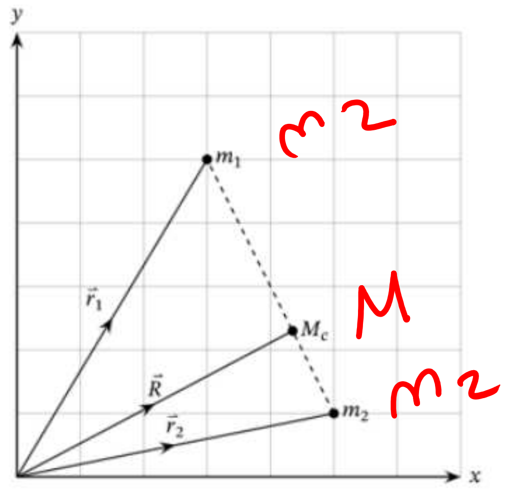
equivalence point
نقطة التعادل

2.	Describe that the location of the center of mass is a fixed point relative to the object or system of objects and does not depend on the location of the coordinate system used to describe it.	Student Book (S.B) S.B/Figure 8.2 Concept Check 8.1	227

سؤال وزاري سابق

Based on the graph below that shows the center of mass of two masses m_1 and m_2, what are the relative magnitudes of the two masses m_1 and m_2?

بناء على الرسم البياني الذي يوضح موقع مركز الكتلة لنظام مكون من كتلتين m_1 و m_2، ما المقادير النسبية للكتلتين m_1 و m_2؟



$m_2 > m_1$

$m_1 < m_2$

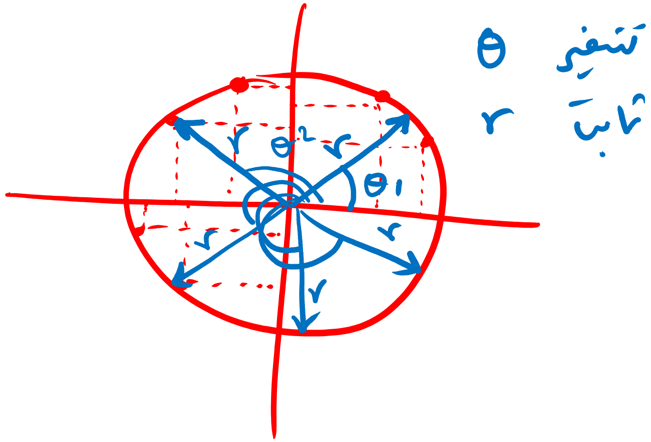
$m_1 > m_2$

$m_1 = m_2$

it is not possible to decide which of the two masses is larger.
لا يمكن تحديد أي الكتلتين أكبر

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

During an object's **circular motion,** its x- and y-coordinates change continuously, but the distance from the object to the center of the circular path stays the same. We can take advantage of this fact by using **polar coordinates** to study circular motion. Shown in Figure 9.3 is the position vector $\vec{r}$, of an object in circular motion. This vector changes as a function of time, but its tip always moves on the circumference of a circle. We can specify $\vec{r}$ by giving its x- and y-components. However, we can specify the same vector by giving two other numbers: the angle of $\vec{r}$ relative to the x-axis, θ, and the length of $\vec{r}$, $r = |\vec{r}|$ (Figure 9.3).



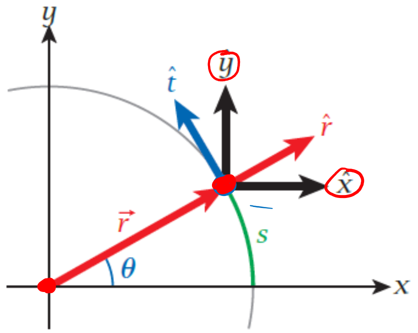


FIGURE 9.3 Polar coordinate system for circular motion.

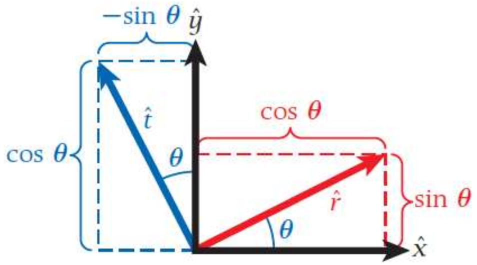


FIGURE 9.4 Relationship between the radial and tangential unit vectors shown in Figure 9.3, the Cartesian unit vectors, and the sine and cosine of the angle.

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

Trigonometry provides the relationship between the Cartesian coordinates x and y and the polar coordinates θ and r:

m cm   m cm   m cm

$$r = \sqrt{x^2 + y^2} \tag{9.1}$$

$$\theta = \tan^{-1}(y/x). \tag{9.2}$$

rad

deg

The inverse transformation from polar to Cartesian coordinates is given by

$$x = r\cos\theta \tag{9.3}$$

$$y = r\sin\theta. \tag{9.4}$$

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

EXAMPLE 9.1 Locating a Point with Cartesian and Polar Coordinates

A point has a location given in Cartesian coordinates as (4,3), as shown in Figure 9.5.

x y

PROBLEM

How do we represent the position of this point in polar coordinates?

$$r = \sqrt{3^2 + 4^2} = 5$$

$$\theta = \tan^{-1}\left(\frac{3}{4}\right) = 37^\circ$$

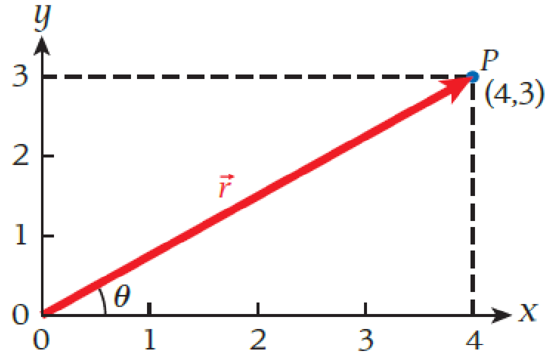


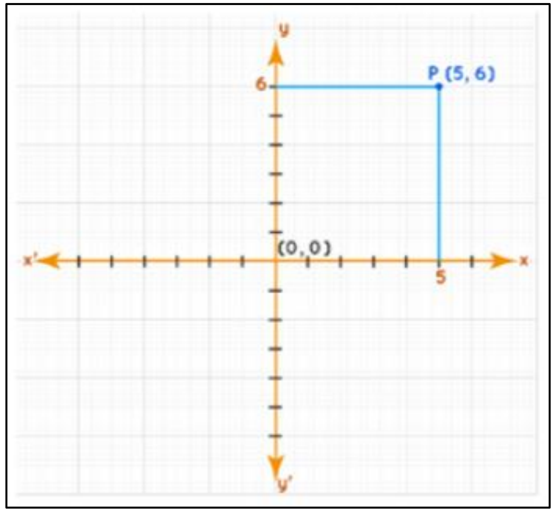
FIGURE 9.5 A point located at (4,3) in a Cartesian coordinate system.

3.	(1) Define the polar coordinate system as a two-dimensional coordinate system such that a point on a plane is defined by its distance r from the origin and the angle θ measured. (2) Express the Cartesian coordinates (x, y) in terms of the polar coordinates (r, θ) and vice versa. (3) Convert polar coordinates to Cartesian coordinates and vice versa.	Student Book (S.B) S.B/Figure 9.3/9.4 Example 9.1	255-256 256

سؤال وزاري سابق

A point P has a location given in Cartesian coordinates as shown in the graph below, how to represent point P in polar coordinates?

يحدد موقع النقطة P بالإحداثيات الديكارتية كما هو موضح بالرسم البياني أدناه، كيف يمكن تمثيل موقع P بالإحداثيات القطبية؟



(7.8, 0.88 rad)

(7.8, ~~50.2~~ rad)

(7.8, ~~0.7~~ rad)

(7.8, ~~40~~ rad)

$r = \sqrt{5^2 + 6^2} = 7.8$

$\theta = \tan^{-1}\left(\frac{6}{5}\right) = 0.88 \text{ rad}$

$\boxed{R}$

4.	Relate the arc length (s), to the radius (r) of the circular path and the angle (θ), measured in radians.	S.B/Figure 9.3 Student Book (S.B)	255 257

Arc Length

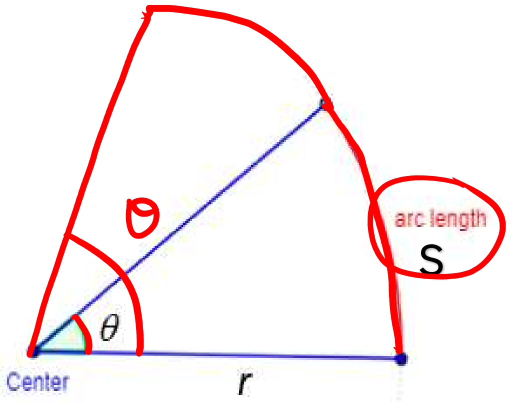
Figure 9.3 also shows (in green) the path on the circumference of the circle traveled by the tip of the vector $\vec{r}$ in going from an angle of zero to θ. This path is called the *arc length*, *s*. It is related to the radius and angle via

θ = rad s = m r = m cm cm

$$\boxed{s = r\theta.} \quad (9.7)$$

s ↑↓ θ ↑↓ r const

For this relationship to work out numerically, the angle has to be measured in radians. The fact that the circumference of a circle is $2\pi r$ is a special case of equation 9.7 with $\theta = 2\pi$ rad, corresponding to one full turn around the circle. The arc length has the same unit as the radius.



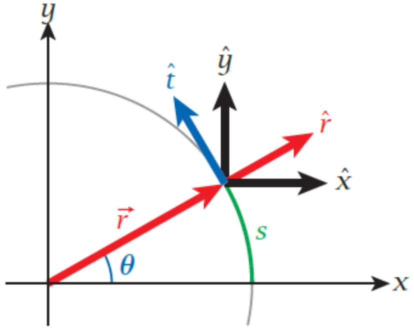


FIGURE 9.3 Polar coordinate system for circular motion.

4.	Relate the arc length (s), to the radius (r) of the circular path and the angle (θ), measured in radians.	S.B/Figure 9.3 Student Book (S.B)	255 257

Practice: Find the arc length of the following circle with a radius of 12 cm.

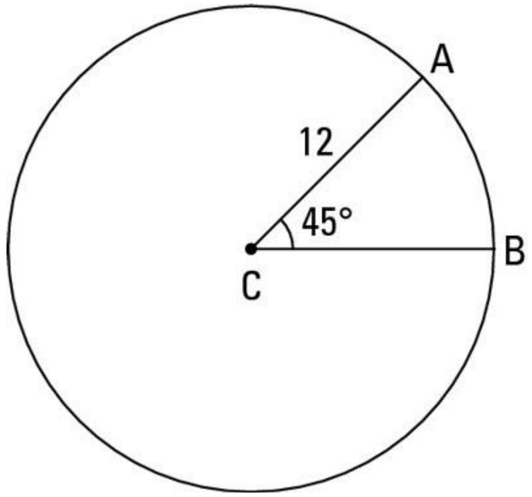
s

$$\theta = 45^\circ \times \frac{\pi}{180^\circ} = \frac{\pi}{4}$$

$$s = r\theta$$

$$= 12\left(\frac{\pi}{4}\right)$$

$$= 3\pi = 9.42 \text{ cm}$$



4.	Relate the arc length (s), to the radius (r) of the circular path and the angle (θ), measured in radians.	S.B/Figure 9.3 Student Book (S.B)	255 257

What is the angle of rotation (in degrees) between two hands of a clock, if the radius of the clock is $0.70\ \mathrm{m}$ and the arc length separating the two hands is $1.0\ \mathrm{m}$?

θ

r

a. 40°

b. 80°

c. 81°

d. 163°

$s = r\theta$

$\frac{s}{r} = \theta \rightarrow \text{rad} \rightarrow \text{degree}$

$\theta = \frac{1}{0.7} = 1.4\ \text{rad} \times \frac{180}{\pi} = 81^\circ$

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(*a*)	260 282

We have seen that the change of an object's linear coordinates in time is its velocity. Similarly, the change of an object's angular coordinate in time is its **angular velocity.** The average magnitude of the angular velocity is defined as

$$\boxed{\bar{\omega} = \frac{\theta_2 - \theta_1}{t_2 - t_1} = \frac{\Delta\theta}{\Delta t}}.$$

Angular velocity measures how fast the angle θ changes in time. Another quantity also specifies how fast this angle changes in time–the **frequency,** f. For example, the rpm number on the tachometer in your car indicates how many times per minute the engine cycles and thus specifies the frequency of engine revolution. Figure 9.9 shows a tachometer, with the units specified as "1/min × 1000"; the engine hits the red line at 6000 revolutions per minute. Thus, the frequency, f, measures cycles per unit time, instead of radians per unit time as the angular velocity does. The frequency is related to the magnitude of the angular velocity, ω, by

turns in 1 s

$$\boxed{f = \frac{\omega}{2\pi} \Leftrightarrow \omega = 2\pi f.} \tag{9.9}$$

This relationship makes sense because one complete turn around a circle requires an angle change of 2π rad. (Be careful–both frequency and angular velocity have the same unit of inverse seconds and can be easily confused.)

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(a)	260 282

Because the unit inverse second is used so widely, it was given its own name, the **hertz** (Hz), for the German physicist Heinrich Rudolf Hertz (1857–1894): 1 Hz = 1 s^{-1}. The **period of rotation,** T, is defined as the inverse of the frequency:

time for 1 revolution

$$\boxed{T = \frac{1}{f}.} \tag{9.10}$$

The period measures the time interval between two successive instances where the angle has the same value; that is, the time it takes to pass once around the circle. The unit of the period is the same as that of time, the second (s). Given the relationships between period and frequency and between frequency and angular velocity, we also obtain

$$\boxed{\omega = 2\pi f = \frac{2\pi}{T}.} \tag{9.11}$$

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises/Q. 9.61.(a)	260 282

EXAMPLE 9.3 Revolution and Rotation of the Earth

PROBLEM

The Earth orbits around the Sun and also rotates on its pole-to-pole axis. What are the angular velocities, frequencies, and linear speeds of these motions?

ω $= \frac{\theta}{t}$

f

$v = r\omega$

نصف قطر

https://youtu.be/X4Kl5bCJN14?feature=shared&t=659

رابط الحل بالتفصيل

5.	Apply the relation for the magnitude of angular velocity in terms of frequency and period of rotation	Example 9.3 Additional Exercises Q. 9.61.(*a*)	260 282

9.61 A boy is on a Ferris wheel, which takes him in a vertical circle of radius 9.00 m once every 12.0 s. T

a) What is the angular speed of the Ferris wheel?

$r = 9\,m$

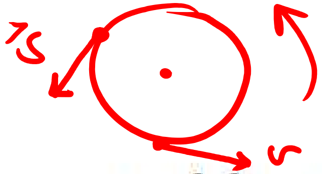
$$\omega = \frac{2\pi}{T}$$

$$= \frac{2\pi}{12} = 0.523 \text{ rad/s}$$

6.	Relate the magnitudes of linear (tangential) and angular velocities for circular motion as, and explain that this relation does not hold for tangential and angular velocity vectors which point in different directions.	Exercises/Q. 9.44	281

linear velocity

$$\boxed{\vec{v} = r\omega\hat{t}.} \tag{9.12}$$

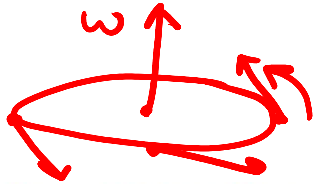


(Again, $\hat{t}$ is the symbol for the tangential unit vector and has no connection with the time, t!)

If we take the absolute values of the left- and right-hand sides of equation 9.12, we obtain an important relationship between the magnitudes of the linear and angular speeds for circular motion:

$v \perp \omega$

$$\boxed{v = r\omega.} \tag{9.13}$$



Remember that this relationship holds only for the *magnitudes* of the linear and angular velocities. Their vectors point in different directions and, for uniform circular motion, are perpendicular to each other, with $\vec{\omega}$ pointing in the direction of the rotation axis and $\vec{v}$ tangential to the circle.

6.	Relate the magnitudes of linear (tangential) and angular velocities for circular motion as, and explain that this relation does not hold for tangential and angular velocity vectors which point in different directions.	Exercises/Q. 9.44	281

9.44 A discus thrower (with arm length of 1.20 m) starts from rest and begins to rotate counterclockwise with an angular acceleration of 2.50 rad/s^2. α

a) How long does it take the discus thrower's speed to get to 4.70 rad/s?

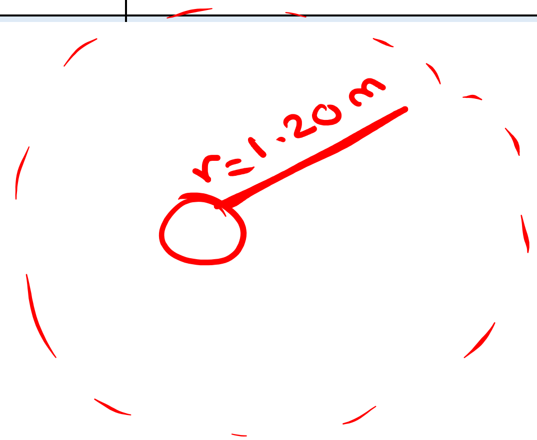
b) How many revolutions does the thrower make to reach the speed of 4.70 rad/s?

c) What is the linear speed of the discus at 4.70 rad/s?

d) What is the linear acceleration of the discus thrower at this point?

e) What is the magnitude of the centripetal acceleration of the discus thrown?

f) What is the magnitude of the discus's total acceleration?



a) $\alpha = 2.50\ rad/s^2$

$\omega_1 = 0$

$\omega_2 = 4.70$

$t = ?$

$\alpha = \frac{\omega_2 - \omega_1}{t}$

$t = \frac{\omega_2 - \omega_1}{\alpha}$

$= \frac{4.70 - 0}{2.50}$

$= 1.88\ s$

(b) find θ

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$= 0 + 0 + \frac{1}{2}(2.5)(1.88)^2$

$= 4.42\ rad$

1 rev = 2π rad

?? = 4.42 rad

rev = $\frac{4.42 \times 1}{2\pi} = 0.70$ rev

6.	Relate the magnitudes of linear (tangential) and angular velocities for circular motion as, and explain that this relation does not hold for tangential and angular velocity vectors which point in different directions.	Exercises/Q. 9.44	281

9.44 A discus thrower (with arm length of 1.20 m) starts from rest and begins to rotate counterclockwise with an angular acceleration of 2.50 rad/s^2.

a) How long does it take the discus thrower's speed to get to 4.70 rad/s?

b) How many revolutions does the thrower make to reach the speed of 4.70 rad/s?

c) What is the linear speed (v) of the discus at 4.70 rad/s (ω)?

d) What is the linear acceleration of the discus thrower at this point?

e) What is the magnitude of the centripetal acceleration of the discus thrown?

f) What is the magnitude of the discus's total acceleration?

$a_c = 0 \Rightarrow a = a_t$

c) $v = r\omega$

$= 1.20 \times 4.70$

$= 5.64\ m/s$

d) $a_t = \alpha r$

$= 2.5 \times 1.20$

$= 3\ m/s^2$

e) $a_c = \frac{v^2}{r}$

$= \frac{(5.64)^2}{1.20}$

$= 26.5\ m/s^2$

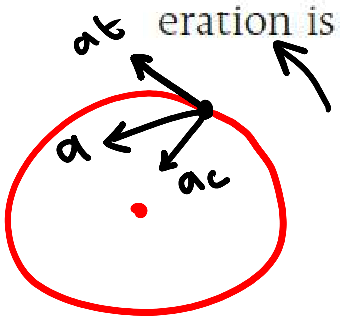
f) $a = \sqrt{a_t^2 + a_c^2}$

$= \sqrt{3^2 + 26.5^2}$

$= 26.6\ m/s^2$

7.	Relate the magnitude of the net acceleration in circular motion to the tangential acceleration and centripetal acceleration (a_c, a, a_t)	Exercises/Q. 9.44 (f) Exercises/Q. 9.46 Additional Exercises/Q. 9.63	281 282
13.	Express the linear acceleration vector for an object in circular motion as $\vec{a}(t)=a_t\hat{t}-a_c\hat{r}$	Student Book (S.B) Exercises/Q. 9.46	262 281
14.	Distinguish between tangential acceleration and radial acceleration, specifying the cause and direction of each.	Student Book (S.B) Exercises/Q. 9.46/9.43	261 281

The rate of change of an object's angular velocity is its **angular acceleration,** denoted by the Greek letter α. The definition of the magnitude of the angular acceleration is analogous to that for the linear acceleration. Its time average is defined as



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

$a_c \rightarrow$ change in direction $\downarrow$ goes in circle

$$\boxed{\vec{a}(t)=r\alpha\hat{t}-v\omega\hat{r}}$$

$\boxed{a_t}$ $\boxed{a_r = a_c}$

$a_t \rightarrow$ change in velocity $\downarrow$ speed up slow down

$a_c = 0 \rightarrow$ moves in a straight line

$a_t = 0 \rightarrow$ goes with constant speed.

7.	Relate the magnitude of the net acceleration in circular motion to the tangential acceleration and centripetal acceleration	Exercises/Q. 9.44 (f) Exercises/Q. 9.46 Additional Exercises/Q. 9.63	281 282

13.	Express the linear acceleration vector for an object in circular motion as $\vec{a}(t)=a_t\hat{t} - a_c\hat{r}$	Student Book (S.B) Exercises/Q. 9.46	262 281
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The rate of change of an object's angular velocity is its **angular acceleration**, denoted by the Greek letter α. The definition of the magnitude of the angular acceleration is analogous to that for the linear acceleration. Its time average is defined as

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

Tangential acceleration:

$$a_t = \frac{dv}{dt}\hat{t} = r\alpha\hat{t}$$

Radial acceleration:

$$a_c = a_r = v\frac{d\hat{t}}{dt} = -v\omega\hat{r}$$

$$\vec{a}(t) = r\alpha\hat{t} - v\omega\hat{r}$$

a_t

$a_r = a_c$

$$a = r\sqrt{\alpha^2 + \omega^4}$$

سؤال وزاري سابق

$\cancel{v} = r\cancel{\omega}$

$20000 \times \frac{2\pi}{60} = 2094 \text{ rad/s}$

A centrifuge rotor is accelerated for 30 s from rest to 20,000 rpm. What is its average angular acceleration?

t $\quad$ $v_1 = 0$, $\omega_1 = 0$ $\quad$ ω

يتم تسريع دوار جهاز الطرد المركزي لمدة 30 s من السكون إلى 20,000 دورة في الدقيقة. ما متوسط تسارعها الزاوي؟

- 70 rad/s^2
- 2100 rad/s^2
- 11.1 rad/s^2
- 333 rad/s^2

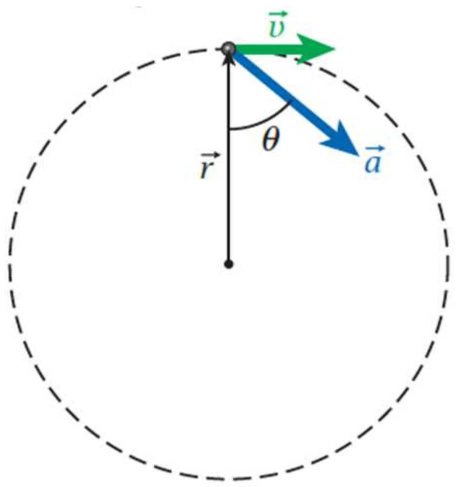
$$\alpha = \frac{\omega}{t} = \frac{2094}{30} = 70 \text{ rad/s}^2$$

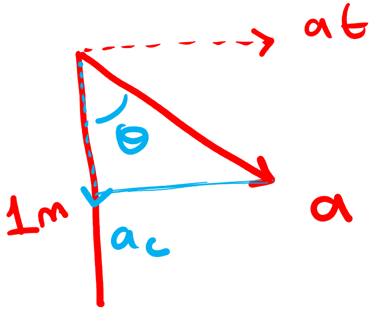
9.44 A discus thrower (with arm length of 1.20 m) starts from rest and begins to rotate counterclockwise with an angular acceleration of 2.50 rad/s^2.

f) What is the magnitude of the discus's total acceleration?

الحل في السابق

•9.46 A particle is moving clockwise in a circle of radius 1.00 m. At a certain instant, the magnitude of its acceleration is $a = |\vec{a}| = 25.0\ \mathrm{m/s^2}$, and the acceleration vector has an angle of $\theta = 50.0°$ with the position vector, as shown in the figure. At this instant, find the speed, $v = |\vec{v}|$, of this particle.





a_c ✓

↓

v

$$\cos\theta = \frac{a_c}{a}$$

$\boxed{D}$

$$a_c = a\cos\theta = 25\cos(50)$$
$$= 16.1\ \mathrm{m/s^2}$$

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

$$r a_c = v^2$$

$$\sqrt{r a_c} = v$$

$$v = \sqrt{1 \times 16.1} = 4.0\ \mathrm{m/s}$$

9.63 A car accelerates uniformly from rest and reaches a speed of 22.0 m/s in 9.00 s. The diameter of a tire on this car is 58.0 cm.

a) Find the number of revolutions the tire makes during the car's motion, assuming that no slipping occurs.

b) What is the final angular speed of a tire in revolutions per second?

$\omega_i = 0$, $v_i = 0$, v_2, t, d, θ, rad/s

$\div 100 = d = 0.58\ m \rightarrow r = \frac{d}{2} = \frac{0.58}{2} = 0.29\ m$

a) $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

$\omega = \omega_0 + \alpha t$

$\alpha = \frac{\omega - \omega_0}{t} = \frac{\frac{22}{0.29} - 0}{9} = 8.4\ rad/s^2$

$\theta = \cancel{\theta_0} + \cancel{\omega_0 t} + \frac{1}{2}\alpha t^2$

$\theta = \frac{1}{2}\alpha t^2 = \frac{1}{2}(8.4)(9)^2 = 340\ rad$

1 rev = 2π rad

?? = 340 rad

$rev = \frac{340 \times 1}{2\pi} = 54\ rev.$

b) $\omega = \frac{22}{0.29}\frac{rad}{s} \times \frac{1\ rev}{2\pi\ rad} = 12.1\ rev/s$

$v = r\omega$

$\frac{v}{r} = \omega$

$\frac{22}{0.29} =$

9.43 A centrifuge in a medical laboratory rotates at an angular speed of 3600. rpm (revolutions per minute). When switched off, it rotates 60.0 times before coming to rest. Find the constant angular acceleration of the centrifuge.

ω_1 rad/s rev $\omega_2 = 0$

$\omega_1 = 3600 \text{ rpm} \times \frac{2\pi}{60} = 120\pi \text{ rad/s}$

$\theta = 60 \times 2\pi = 120\pi \text{ rad}$

$\alpha = ?$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$0 = (120\pi)^2 + 2\alpha(120\pi)$

$-(120\pi)^2 = 2\alpha(120\pi)$

$\frac{-(120\pi)^2}{2 \times 120\pi} = \alpha$

$\alpha = -188 \text{ rad/s}^2$

End of part 1

(see you in part 2 👋)

Ms. Asmaa Alhameed

Physics Teacher

Telegram: @Asmaa_Alhameed

Links: https://qrco.de/bf644T

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