Wrocław University of Science and Technology

Physics

JZL1001913C

summer semester

2020/2021

Wednesday, 18:20 - 19:50

Friday, 18:20 - 19:50

virtual room (ZOOM)

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https://majsylw.netlify.app/

room 213, building L-1

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Outline

- Introduction - Physics rules the world
- Motion phenomena - Kinematics
- Motion phenomena - Dynamics
- **Rotational motion**
- Harmonic motion
- Gravitational field
- Relativistic phenomena
- Basics of Thermodynamics
- Principles of Thermodynamics
- Kinetic theory of matter
- Electrostatics
- Electric current
- Magnetic field
- Vibrations and electromagnetic waves
- Optics
- Quantum nature of radiation
- Nuclear Physics

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Dynamics - rewiev

Energy	1 Joule = 1 kg • m^2/s^2

Potential Energy (gravity)

PE_{grav} = mass • g • height

PE_{grav} = m • g • h

Elastic Energy (springs)

PE_{spring} = 0.5 • k • x^2

where k = spring constant

x = amount of compression (relative to equilibrium position)

Kinetic Energy (movement)

KE = 0.5 • m • v^2

where m = mass of object

v = speed of object

Quantities:
- Force
- Momentum
- Work
- Power
- Energy

Force $F = ma$	Unit 1 Newton =1kg * m/s^2
Momentum p = m • v	Unit 1 kg * m/s^2
Work $W_F = F \cdot \Delta x$	Unit 1 Joule = 1 kg • m^2/s^2
Power $P = \frac{\mathrm{d}E}{\mathrm{d}t} = \frac{\mathrm{d}W}{\mathrm{d}t}$	Unit 1 Watt = 1 J/s = =1kg * m^2/s^3

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Dynamics - rewiev

Newton's First Law: The Law of Inertia

Every body remains in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed thereon

$$\vec{F}_{net} = m\vec{a} \quad \text{(Newton's second law)}$$

Laws:
- Three dynamics laws
- Momentum Conservation Principle
- Energy Conservation Principle

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Main point of Newton's third law:
ACTION = REACTION
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Please see additional materials:
https://www.youtube.com/watch?v=UGTmOCJ0NKI&list=UUhHQqNoxwkTnIRC8zEvLsNw

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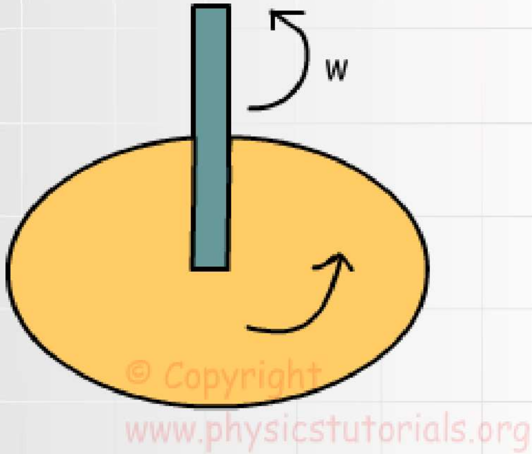
Rotational motion

Rotational motion (or we can say circular motion) can be analyzed in the same way of linear motion. Today, we will find the velocity, acceleration and other concepts related to the circular motion. Uniform circular motion is one of the example. In uniform circular motion speed of the object is always constant and direcrotational motion imagetion is changing. Thus, velocity of the object is changing and as a result object has acceleration. Some concepts will be covered like: rotational speed (angular speed), tangential speed (linear speed), frequency, period, rotational inertia of the objects, torque, angular momentum and its conservation.



Please see course:
https://www.khanacademy.org/science/ap-physics-1/ap-torque-angular-momentum#introduction-to-angular-motion-ap

Angular displacement θ

A particle moves in a circle of radius r. Having moved an arc length s, its angular position is θ relative to its original position, where

$$\theta = \frac{s}{r}$$

In mathematics and physics it is conventional to use the natural unit radians rather than degrees or revolutions. Units are converted as follows:

$$1 \text{ revolution } = 360^\circ = 2\pi \text{ radians, and}$$
$$1 \text{ rad} = \frac{180^\circ}{\pi} \approx 57.27^\circ .$$

An angular displacement is a change in angular position:

$$\Delta\theta = \theta_2 - \theta_1$$

where $\Delta\theta$ is the angular displacement, θ_1 is the initial angular position and θ_2 is the final angular position.

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Speed in circular motion

The formula of the speed in linear motion is;
Speed=distance/time

Speed in circular motion is also defined as the distance taken in a given time. Thus, speeds of the points given in the picture below are;
V =Distance/time

If the object has one complete revolution then distance traveled becomes; **2πr** which is the circumference of the circle object.

V_A **= 2πr/time** **(tangential speed)**

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Period and frequency

Period: Time passing for one revolution is called ***period***. The unit of period is **second**. **T** is the representation of period.

Frequency: Number of revolutions per one second. The unit of frequency is **1/second**. We show frequency with letter **f**. The relation of **f** and **T** is;
f=1/T [1 Hz = 1/s]

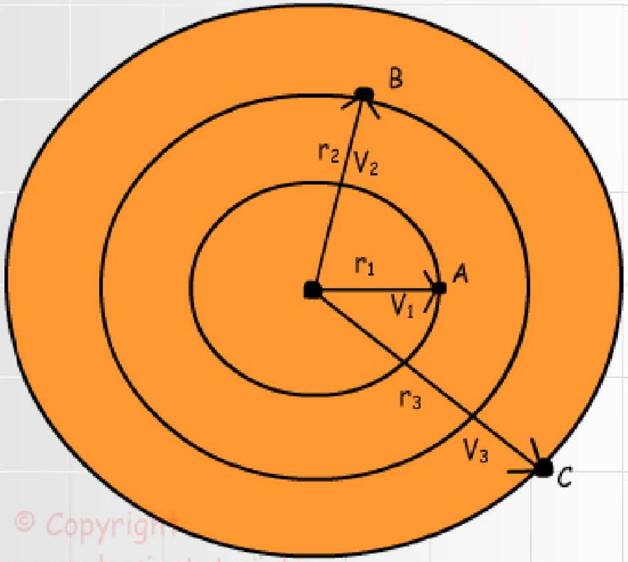
Sum up

Now; lets' sequence the velocities of the points on given picture.

Since the velocity or speed of the points on rotating object is linearly proportional to the radius **r3>r2>r1**;

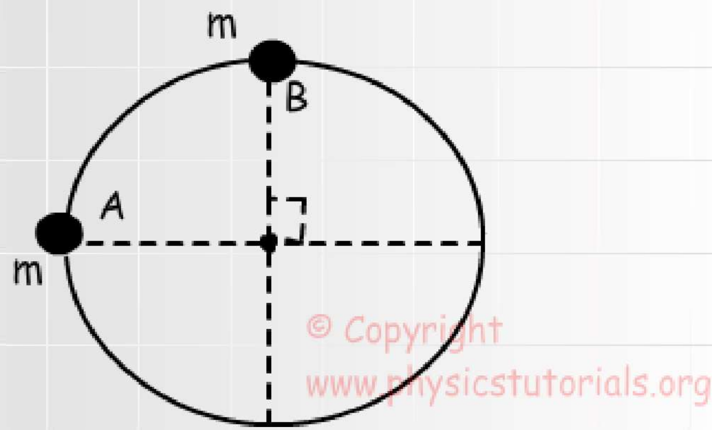
V3>V2>V1

To sum up, we can say that tangential speed of the object is linearly proportional to the distance from the center. Increase in the distance results in the increase in the amount of speed. As we move to the center speed decreases, and at the center speed becomes zero. We use the same unit for tangential speed as linear motion which is "m/s".



Example 1

A particle having mass m travels from point A to B in a circular path having radius R in 4 seconds. Find the period of this particle.



Particle travels one fourth of the circle in 4 seconds. Period is the time necessary for one revolution.

So,
T/4=4s
T=16s.

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Example 2

If the particle having mass m travels from point A to B in 4 seconds find the tangential velocity of that particle given in picture below. ($\pi=3$)

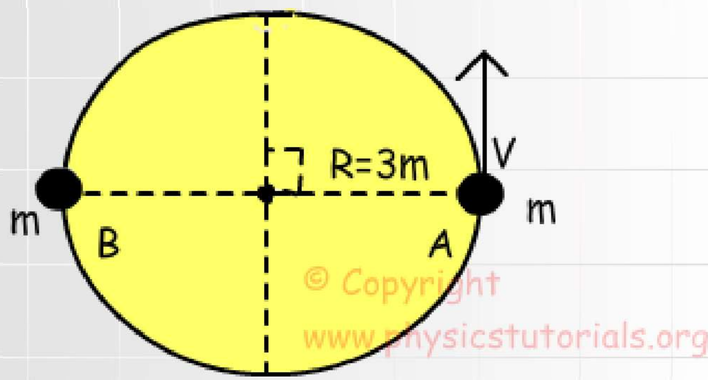
We first find the period of the motion. If the particle travels half of the circle in 4 seconds;

$T/2=4s$

$T=8s$

$v=2\pi R/T$

$v=2*3*3m/8s=9/4$ m/s tangential speed of the particle



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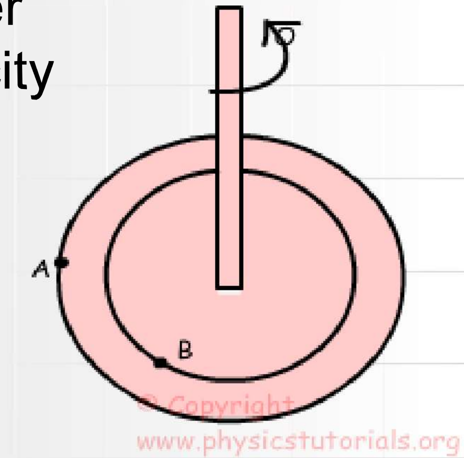
Angular velocity

Look at the given picture. If the platform does one rotation then points A and B also does one rotation. We define angular velocity as “change of the angular displacement in a unit of time”. The unit of angular velocity is revolution per unit time or radians per second. We show angular velocity with the Greek letter “**ω**” omega.



Average Velocity= Circumference of the Circle/Time

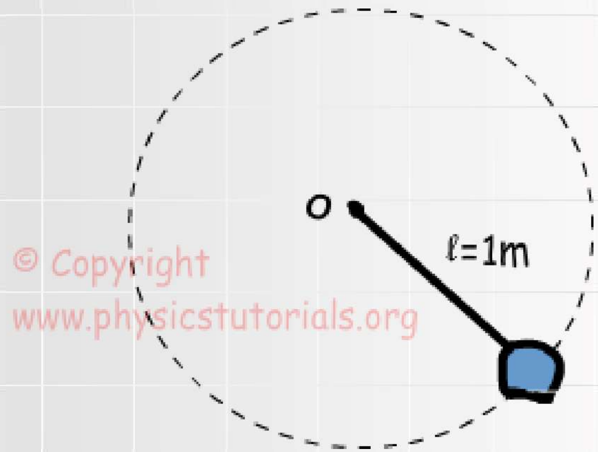
Average Speed/Velocity = 2πr/T

where, T is the period of the system and r is the radius of the revolution.

ω=2π/T=2πf where, f is frequency and T is the period

Example 1

If the stone does 6 rotations in 1 second find the angular velocity of it.



If the stone does four rotations in one second then its frequency becomes 6.
$f=6s^{-1}$
$T=1/f=1/6s$
$\omega=2\pi/T=2*3/(1/6s)=36$ rad/s

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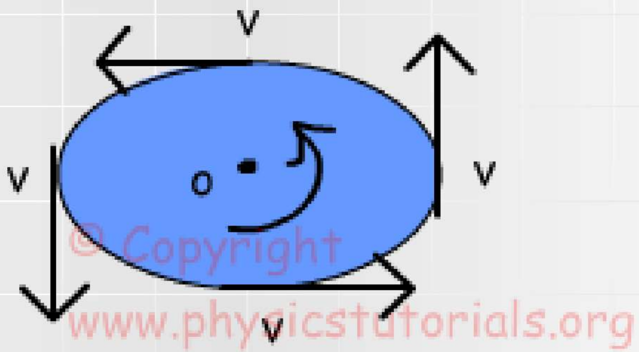
Angular acceleration

The speed of the system is constant and we show it with “**ω**”. However, as you can see direction of the angular acceleration speed changes as time passes and always tangent to the circle. Change in the direction of velocity means system has acceleration which is called angular acceleration.

Since the acceleration is;

$$\boldsymbol{\alpha = (\omega_{final} - \omega_{initial})/t}$$



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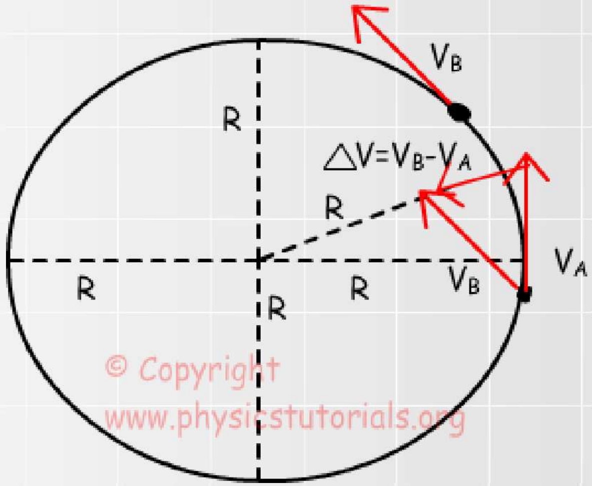
Centripetal acceleration

Direction of the acceleration is same as the direction of change of velocities.



We should find the direction of the changes in the velocity by using vector properties. Let’s show how we find the direction of acceleration. Picture shows the change in the direction of velocity. We can see direction of the resultant velocity vector is towards to the center of the circle. Because of the direction of acceleration, we call it centripetal acceleration.

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Mathematical formulas

Mathematical representation of centripetal acceleration is

$$a_{centripetal} = -\frac{4\pi^2 r}{T^2}$$

“-“sign in front of the formula shows the direction with respect to the R position vector.

We can rewrite centripetal acceleration in terms of angular velocity and tangential velocity.

$$a_{centripetal} = -\omega^2 r \quad \text{or,} \quad a_{centripetal} = \frac{v^2}{r}$$

Example 1

If the tangential speed of the object is 3m/s which is doing circular motion on a path of radius 2m, find the centripetal acceleration of it.

$$a_{centripetal} = -\frac{4\pi^2 r}{T^2}$$

Or we can rewrite it as;

$a = V^2/r = (3m/s)^2/2m = 4.5m/s^2$

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Equations of kinematics

When the angular acceleration is constant, the five quantities angular displacement θ, initial angular velocity ω_i, final angular velocity ω_f, angular acceleration α, and time t can be related by four equations of kinematics:

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

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

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

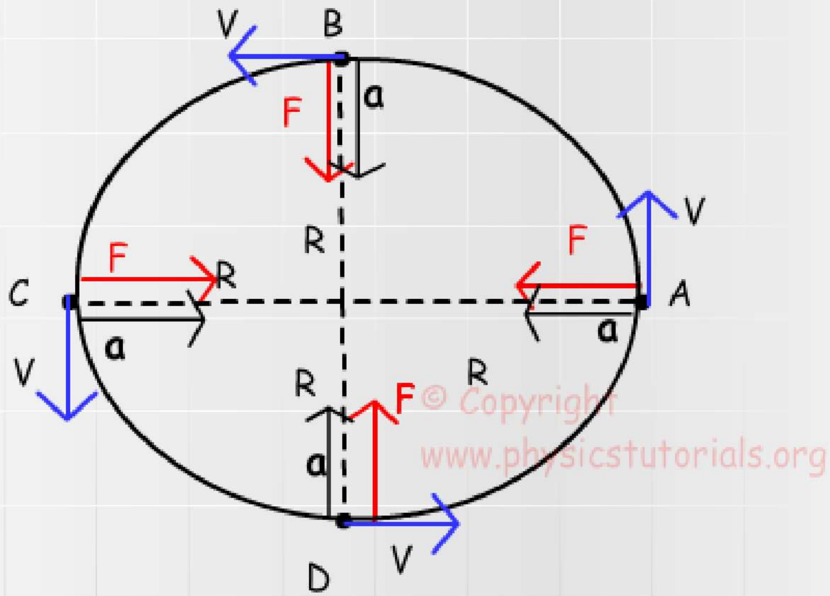
$$\theta = \frac{1}{2}\left(\omega_f + \omega_i\right) t$$

Centripetal Force

In Newton's Second Law of motion we said that:
if there is a force than our mass has acceleration.

In this case we find the acceleration first, so if there is acceleration then we can say there must be also a force causing that acceleration. The direction of this net force is same as the direction of acceleration which is towards to the center.

Don't forget! Direction of acceleration and force is always same.



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Mathematical formulas

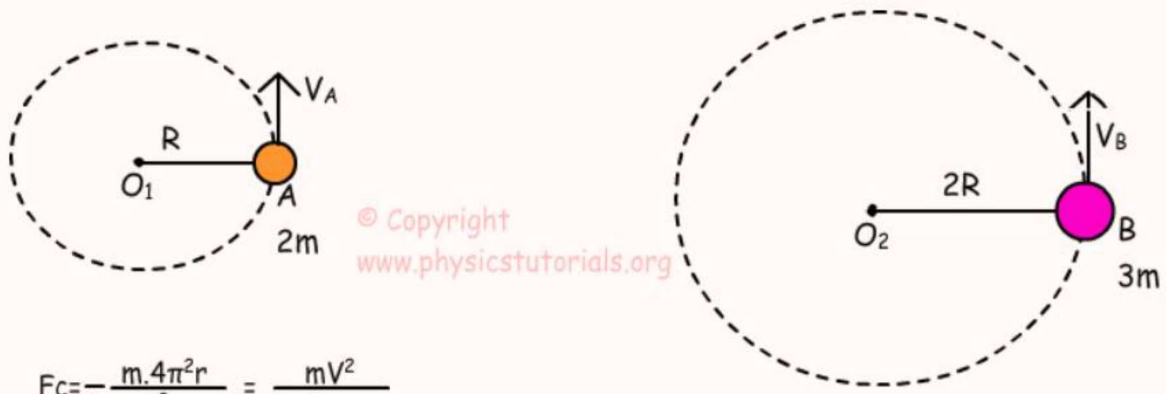
From the Newton's Second Law of Motion;
$F=m*a$

$F_c=-m4\pi^2r/T^2$ or **$F_c=mv^2/r$**

Where:
- m is mass of the object,
- r is the radius of the circle,
- T is the period,
- V is the tangential speed.

Example 1

Two objects A and B do circular motion with constant tangential speeds. Object A has mass 2m and radius R and object B has mass 3m and radius 2R. If the centripetal forces of these objects are the same find the ratio of the tangential speed of these objects



$$F_c = \frac{m.4\pi^2 r}{T^2} = \frac{mV^2}{R}$$

$$F_{cA} = \frac{2mV_A^2}{R}$$

$$F_{cB} = \frac{3mV_B^2}{2R}$$

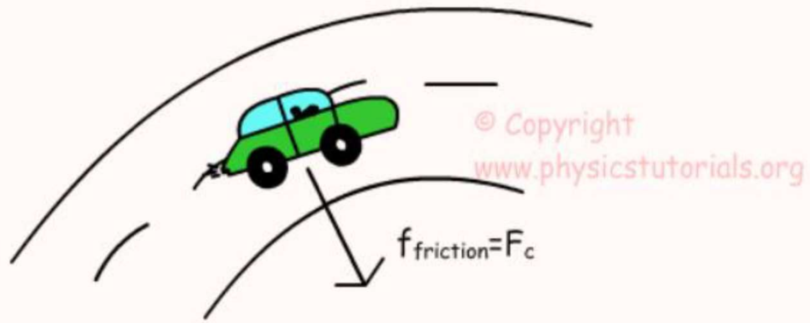
$$F_{cA} = F_{cB}$$

$$\frac{2mV_A^2}{R} = \frac{3mV_B^2}{2R}$$

$$\frac{V_A}{V_B} = \frac{\sqrt{3}}{2}$$

Example 1

A car makes a turn on a curve of having radius 8m. If the car does not slide find the tangential velocity of it. (Coefficient of friction between the road and the tiers of the car =0, 2 and g=10m/s²)



$f_{friction}= \mu .N$

$f_{friction}= 0,2.m_{car}.g$

$0,2.m_{car}.g = \frac{m_{car}.V^2}{R}$

$0,2.10m/s^2 = \frac{V^2}{8m}$

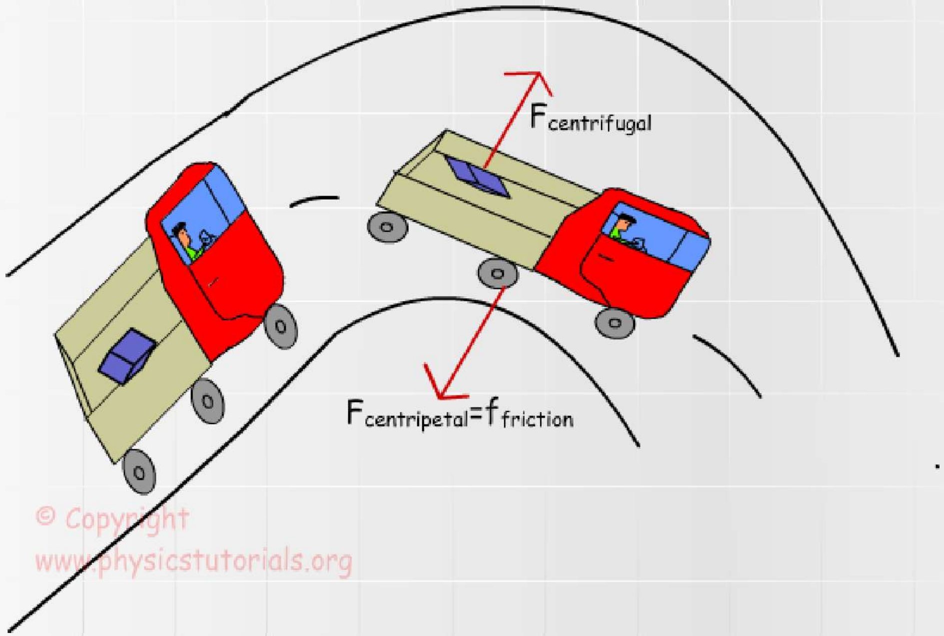
V=4m/s

$F_c=\frac{m_{car}.V^2}{R}$

Since both sides of the equation has mass they cancel each other so, we don't need the value of it.

Centrifugal Force

In daily life we feel a force on us while we are in a system doing circular motion. For instance, when a car goes around a curve we feel that as if something pulls us outward to the center of that curve. In real, of course there is no such a force exerting on us. In previous topic we explained the centripetal force and gave some examples to it. Now, we use again same examples to clarify centrifugal force which means “outward from the center”.



Example
(for picture in previous slide)

A truck moving in a straight line carries a box. During linear motion box does not move and has the same velocity of the truck. However, when the truck goes around a curve, box starts to move outward to the center of the curve as if an unknown force pulls it. We also feel this force when in a bus or car while it is doing circular motion. Is there a force pulling us outward from the center? The answer is of course NO! Let me explain this complex situation with Newton's Laws of Motion. We have said that for having acceleration there must be an unbalanced net force on that system. Here, a friction force between the road and the tiers of the truck becomes our unbalanced net force. It changes the direction of motion and truck does circular motion. On the other hand, the friction between the box and the surface of the truck is not enough to make it does also circular motion. Because of the Newton's First Law of Motion "Law of Inertia" box tends to move in a straight line. Thus, it slides on the truck and feels like something pulls it outward from the center. This is only inertia of the box, in real there is no centrifugal force.

Torque

We define torque as the capability of rotating objects around a fixed axis. In other words, it is the multiplication of force and the shortest distance between application point of force and the fixed axis. From the definition, you can also infer that, torque is a vector quantity both having direction and magnitude. However, since it is rotating around a fixed axis its direction can be clockwise or counterclockwise. During the explanations and examples we give the direction “**+**” if it rotates clockwise direction and “**-**” if it rotates counterclockwise direction. Torque is shown in physics with the symbol “**τ**”. You can come across torque with other name “moment”.

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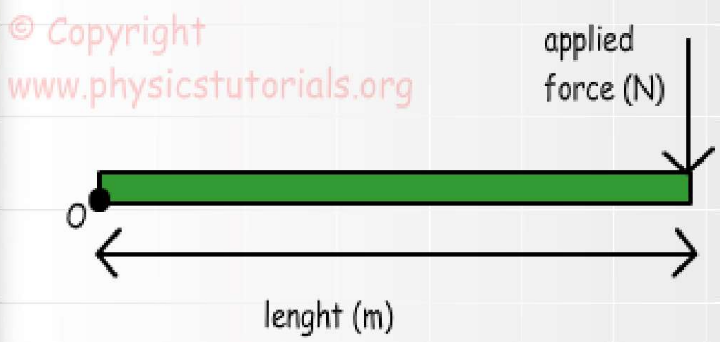
Torque



How can we find the shortest distance between the applied force and fixed axis? All you know that, shortest distance between two points is the straight line connecting them. In this situation distance connecting these two points is the length of the object. Direction of the torque is “+” because force rotates the object in clockwise direction. (We ignore the weight of the object n all situations given above.)

Thus, we can write the torque equation like:

T=Applied Force x Distance

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Additional materials

Lectures:
https://www.if.ufrj.br/~coelho/Newman/Newman07.pdf

Videos:
https://www.khanacademy.org/science/ap-physics-1/ap-torque-angular-momentum#introduction-to-angular-motion-ap

Cheetsheets:
https://www.physicstutorials.org/home/rotational-motion/rotational-motion-cheat-sheet

Motion phenomena – Rotational motion

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All right. So if you go to our website today, you will find I've assigned some problems and you should try to do them. They apply to this chapter. Then next week we'll do anothers problems connected with gravity and harmonic motion.

Translational Motion		Rotational Motion
$v = v_0 + at$	$\longrightarrow$	$\omega = \omega_0 + \alpha t$
$x = x_0 + v_0 t + \frac{1}{2} a t^2$	$\longrightarrow$	$\theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2$
$v^2 = v_0^2 + 2ax$	$\longrightarrow$	$\omega^2 = \omega_0^2 + 2\alpha(\theta - \theta_0)$

Where

- θ_0 = initial angular displacement of the rotating body
- ω_0 = initial angular velocity of the body.
- $\propto$ = angular acceleration, which is constant is this section.

Closer look at calendar

	FEBRUARY	MARCH					APRIL				MAY					JUNE			JULY	
MON	22	1	8	15	22	29	5	12 Mon O	19	26	3	10	17	24	31	7	14	21	28	5
TUE	23	2	9	16	23	30 Fri E	6	13	20	27	4	11	18	25	1	8	15	22	29	6
WED	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2 Thu E	9	16	23	30	7
THU	25	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8
FRI	26	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9
SAT	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10
SUN	28	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	4	11
E - EVEN O - ODD	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E

Lecture
Exercise
Revision/exam

Wednesday, 18:20 - 19:50
Friday, 18:20 - 19:50

Office hours:
Monday, 20:30 - 21:30
virtual room

Quizz

Kahoot link:
https://kahoot.it/challenge/02469638?challenge-id=459c69ba-0699-474d-ae7d-12916780bd23_1615632003886

Deadline: 24th March 2021, 18:00