Rotational Motion

① Main idea : Ⓐ What is the difference between Rotational & Circular Motion ?!
Ⓑ What kind of relationship it has with transitional Motion (linear vector) ?!
Ⓒ What affects Rotational Motion ?!
Ⓓ Understanding the whole story !!

② Difference between Rotational & circular motion

↳ Rotational Motion
- ↳ is the motion of an object around an internal axis (axis inside the object itself)
- ↳ as a ball spinning or revolving around itself ...
- ↳ has 2 forces acting upon it :
  - ↳ Centripetal (F_c) ($F_{\parallel}$)
    - ↳ Maintains the object's shape (due to intermolecular forces) ...
    - ↳ points towards the axis of rotation ((usually center of mass)) ...
  - ↳ Tangential (F_T) ($F_{\perp}$)
    - ↳ it's the reason behind the change of Rotation speed ...
    - ↳ always tangent to the object ((perpendicular to radius))

↳ Circular Motion
- ↳ is the motion of an object around an external axis (axis separate than the object)
- ↳ as a car turning around a circular track ...
- ↳ has 2 forces acting upon it :
  - ↳ Centripetal (F_c) ($F_{\parallel}$)
    - ↳ Maintains a uniform circular Motion ((due to gravity, friction, or tension))
    - ↳ points toward the center of the circle ...
  - ↳ Tangential (F_T) ($F_{\perp}$)
    - ↳ it's the reason behind the change of circular speed ...
    - ↳ always tangent to the circle ((perpendicular to radius))

③ What kind of relationship does a Rotational motion have with transitional Motion ?!

(linear) $\boxed{r}$ (polar)

Transitional $\rightarrow$ Rotational   Rotational Kinematics   Direction of (θ, ω, α)

$S = r \cdot \theta$

$V_T = r \cdot w$

$a_T = r \cdot \alpha$

$a_c = r \cdot w^2$

$\left.\begin{matrix} a_T \\ a_c \end{matrix}\right\} a_{net}$

$\underbrace{\quad}$ angular $\underbrace{\quad}$

$W_f = \alpha \cdot \Delta t + W_i$

$\Delta\theta = \frac{1}{2} \cdot \alpha \cdot \Delta t + W_i \cdot \Delta t$

$2 \cdot \alpha \cdot \Delta\theta = W_f^2 - W_i^2$

$\Delta\theta = \frac{W_f + W_i}{2} \cdot \Delta t$

$\Delta\theta = \#\text{ revolution} \cdot 2\pi$

curl right fingers to to the direction of rotation... and the thumb points to the direction of (θ, w, α)

$w = \frac{d\theta}{dt}$, $\alpha = \frac{dw}{dt} = \frac{d^2\theta}{dt^2}$

$$\boxed{T = \frac{\Delta t}{\#\text{ revolution}}}$$

$$\boxed{T = \frac{2\pi r}{V_T}}$$

④ What affects Rotational Motion ?!

⇒ Torque : how much a force causes an object to rotate about an axis... it makes things spin...

$$\boxed{\tau = r \cdot F_T}$$

$$\boxed{\tau = I \cdot \alpha}$$

$$\boxed{F_T = F \cdot \sin\theta}$$

$$\boxed{I = \sum_{i=1}^{n} m_i \cdot r_i^2}$$

⇒ What affects Spinning speed (W) ?!

↳ External force, depends on:

- ↳ How much force exerted → (F)
- ↳ How far from axis of rotation → (r)
- ↳ How much (F) is perpendicular to (r) → $(\sin\theta)$

↳ Moments of inertia (I)

↳ the closer the mass is to the axis of rotation, the easier it is to spin the object, and requiring lesser tangential force to produce the same amount of spinning...

$$\boxed{KE_{\text{Rotational}} = \frac{1}{2} \cdot I \cdot W^2}$$

⇒ $\boxed{E_{total} = K + K_{rot} + U}$ $\boxed{\Delta E = \Delta K + \Delta K_{rot} + \Delta U = 0}$

If an object is rolling down a hill, then the stored potential energy goes to both linear & Rotational kinetic energy...

⑤ Understanding the whole story ?!

↳ In both cases, as the tangential force increases, the rotation or circulation speed increases... therefore, increasing the centripetal force required to maintain the object's shape or uniform circular motion... meaning there is a maximum speed at which the object maintains its Rotational or circular Motion... for simplicity, we either maintain a constant speed (no tangential force) or if the speed is changing, we calculate at a certain period of time...

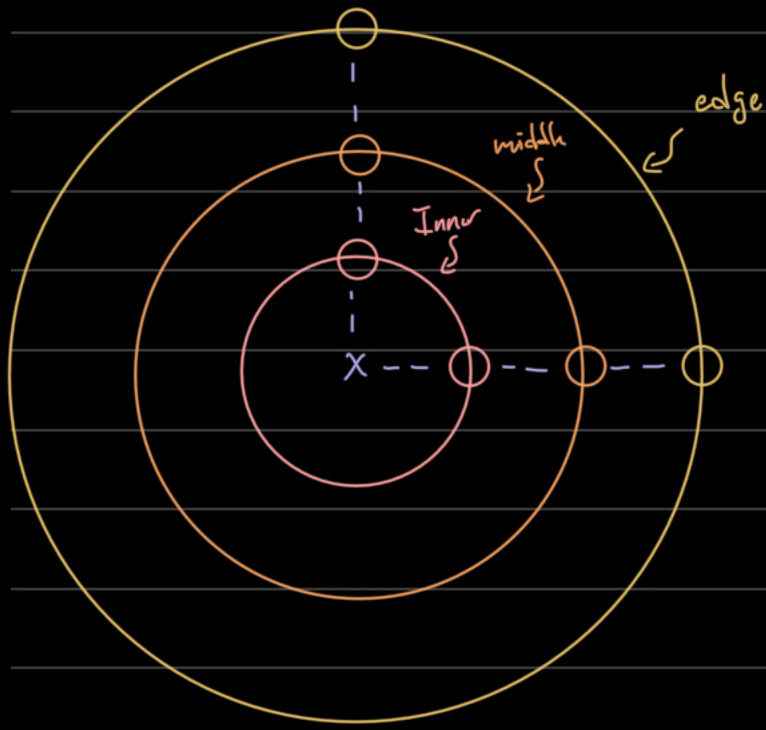
↳ In Rotational Motion, if we zoom inside the object, the molecules move in a circular path... and its movement is restricted by its neighboring molecule... However, the farther away the molecule from center of rotation, the more tangential force is required for all molecules to have the same period, angular acceleration, & angular speed... as a consequence, enabling the object to Rotate as one... as a result, when an external tangential force is applied to the edge of an object, the force is not distributed evenly between molecules... and that is why the edge of an object always breaks first when the object is rotating at really high speeds...

(r) increase → (F_T) increases → (a_T) increases → (V_T) increases → (a_c) increases → (F_c) increases

⇓ ⇓

(I) increases → (I) increases ⇒ For every point on an object to maintain the same $((T, \alpha, \omega))$...

Therefore, if we say a person is rotating with the merry-go-round, then that person must have the same $((T, \alpha, \omega))$ since its one with the system...



$((d \propto r))$

Distance the molecules travels $= r \cdot \theta$ (90°)

⇓

Inner molecule ________

middle molecule ____________

edge molecule ________________

For the molecules to finish their own distances at the same time...

Inner		middle		edge
V_T	<	V_T	<	V_T
a_T	<	a_T	<	a_T
F_T	<	F_T	<	F_T