Spinn: $L = I\,\omega$ = **konstant !**

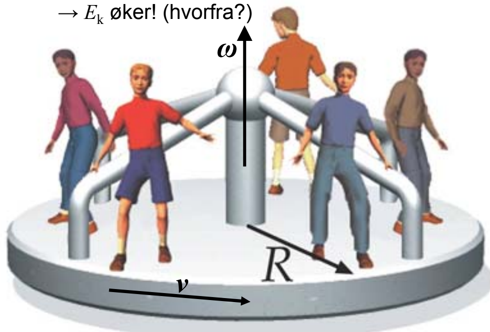
Personer inn mot sentrum: $I = \Sigma\, m_i\, r_i^2$ avtar | ω må øke!

Ikke stivt legeme!

Kinetisk energi: $E_k = ½\, I\, \omega^2 = ½\, L\, \omega$

→ L konstant, ω øker

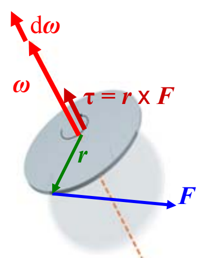
→ E_k øker! (hvorfra?)



Spinn for fallende katt bevart?

Katter lander
- alltid på føttene!

L = **0** ved start og ved slutt
L = **0** underveis !?



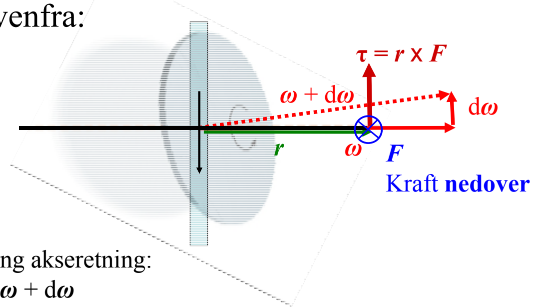
Raskere rotasjon om samme akse:
$\boldsymbol{\omega} \rightarrow \boldsymbol{\omega} + \mathrm{d}\boldsymbol{\omega}$ alle i samme retning
(N2-rot): $\boldsymbol{\tau}\,\mathrm{d}t = I\ \mathrm{d}\boldsymbol{\omega}$
=> $\boldsymbol{\tau}$ i samme retning som $\mathrm{d}\boldsymbol{\omega}$
=> $\boldsymbol{F}$ som i figuren

Hva hvis akseretningen skal endres?

Gyroskop

1. Lodd holder hjulet i balanse
2. $L = I\omega$ holdes konstant når roterer
   → gyrokompass
3. Stor motstand mot endring
4. Endring av akseretning ved kraft normalt på endringen

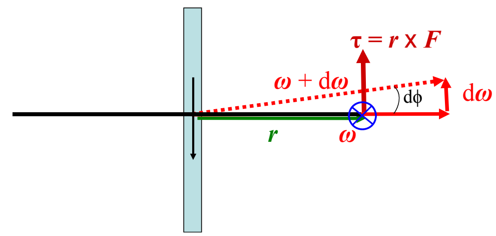
Endring av akseretning
Sett ovenfra:



Endring akseretning:
$\boldsymbol{\omega} \rightarrow \boldsymbol{\omega} + \mathrm{d}\boldsymbol{\omega}$

(N2-rot): $\boldsymbol{\tau}\, \mathrm{d}t = I\ \mathrm{d}\boldsymbol{\omega}$
=> $\boldsymbol{\tau}$ i samme retning som d$\boldsymbol{\omega}$
=> $\boldsymbol{F}$ nedover

Med vedvarende *F* får vi **presesering**

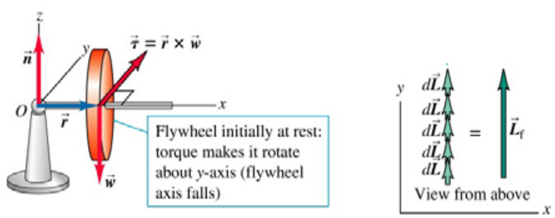


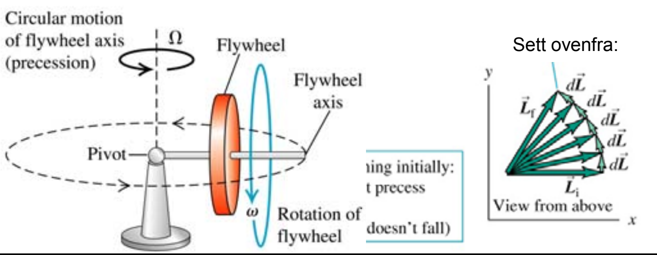
$$\mathrm{d}\phi = \frac{\mathrm{d}\omega}{\omega}$$

$$\Omega_p = \frac{\mathrm{d}\phi}{\mathrm{d}t} = \frac{\mathrm{d}\omega}{\mathrm{d}t}\frac{1}{\omega} \overset{\text{(N2-rot)}}{=} \frac{\tau}{I}\frac{1}{\omega} = \frac{Fr}{I\omega}$$

Sykkelhjul

Ikke-roterende hjul:





Rotasjon av stive legemer

- Treghetsmoment $I = \Sigma\, r_i^2\, m_i$ (om en gitt akse)
- Rotasjonsenergi $E_k = ½\, \Sigma\, m_i\, v_i^2 = ½\, I\, \omega^2$
- Kraftmoment: $\boldsymbol{\tau} = \boldsymbol{r} \times \boldsymbol{F}$
- Spinn (dreieimpuls) $\boldsymbol{L} = \boldsymbol{r} \times m\, \boldsymbol{v}$
- Spinnsatsen (N2-rot): $\boldsymbol{\tau} = \mathrm{d}/\mathrm{d}t\, \boldsymbol{L}$
- Ingen ytre moment (N1-rot): $\boldsymbol{L}$ = konst.

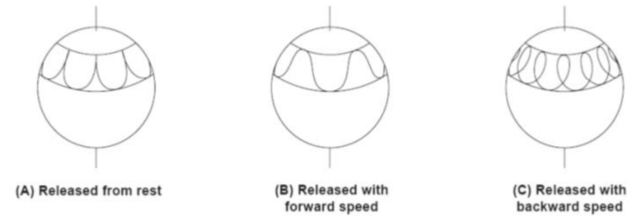
stive legemer:
$= \boldsymbol{I}\ \boldsymbol{\omega}$
$= \boldsymbol{I}\ \mathrm{d}/\mathrm{d}t\, \boldsymbol{\omega}$

Matematisk forklaring av fysikken ofte eneste mulige

Richard Feynman (am. fysiker/pedagog, 1918-1988):

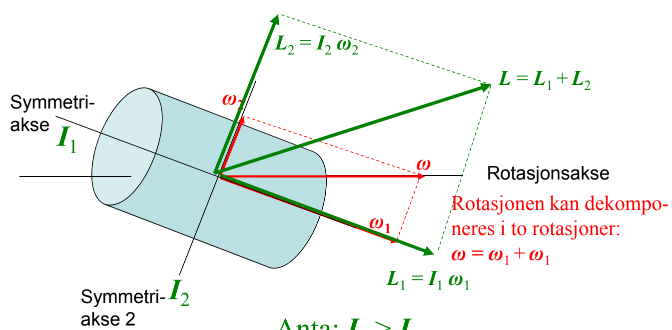
"…many simple things can be deduced mathematically more rapidly than they can really be understood in a fundamental or simple sense. This is a strange characteristic, and as we get into more and more advanced work there are circumstances in which mathematics will produce results which *no one* has really been able to understand in any direct fashon."

Nutasjon



Rotasjon om akse ikke-parallell med symmetriakse

(Ikke pensum)
Mer i LL kap 6.11



Anta: $I_2 > I_1$

Da er **ikke** L parallell med ω

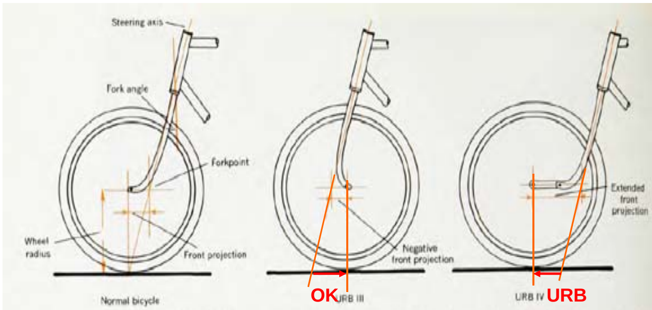
L endrer altså retning under rotasjonen

Hva betyr gyroeffekten for å holde sykkel oppe?

Mr. Jones testet dette med hjul som roterte motsatt retning, dvs. motsatt gyroeffekt.

=> En URB (UnRidableBicycle)?

URB = UnRidableBicycle!?



FRONT-FORK GEOMETRY. On left is a normal bicycle. Center shows URB III with reversed forks giving a negative front projection, and on right is URB IV with extended front projection. —FIG. 2

Sykkelens stabilitet, referanser:

D.E.H. Jones. Physics Today, April 1970, pp. 34-40 (lenke i forelesningsplan)
http://hyperphysics.phy-astr.gsu.edu/hbase/mechanics/bicycle.html#c2
Lowell, J. and McKell, H. D., "The Stability of Bicycles", Am. J. Phys. 50 (1982), pp. 1106-1112.

Snøsykler (snowbikes)

"Counter-steering"

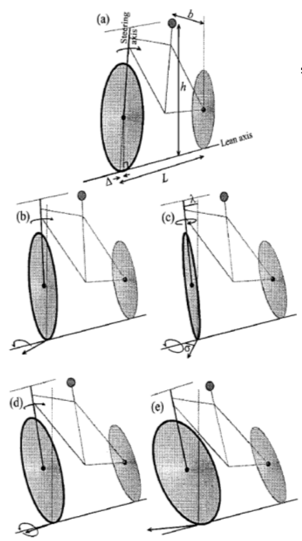


Fig. 1. A counter-steered right turn, as described in the text. The bike geometry is shown in (a) and (c). The center of mass is represented by the filled circle at the location of the seat. The arcs around the steering axis and the lean axis show the direction and approximate magnitude of the torque applied to the handlebars and the net leaning torque.