Toggle Mechanism Force Multiplication

Output force, mechanical advantage, link force and remaining stroke of a symmetrical toggle (knee) joint as the links approach the straight position.

Method: Equilibrium of a toggle joint

Input parameters

Unit system: SI

Parameter	Value	Unit
Force applied at the knee (perpendicular to the output)	0.50000	kN
Link angle from the straight line	5.0000	°
Link length	200.00	mm

Calculated results

Parameter	Value	Unit
Output force along the line of the links	2.8575	kN
Mechanical advantage	5.7150	
Force in each link	2.8684	kN
Output stroke left until the links are straight	1.5221	mm

Notes for this case

• Two equal links meeting at a knee and pushed sideways by F carry F/(2 sin θ) each, whose components along the output line add to P = F/(2 tan θ). As the links straighten (θ → 0) the force multiplication grows without limit while the remaining stroke 2l(1 − cos θ) shrinks to zero, which suits presses, clamps, stone crushers and circuit breakers that need a large force over a short final movement. Friction in the pins and elasticity of the frame limit the real force.

Formula and method

$$P = \frac{F}{2\tan\theta}, \quad F_l = \frac{F}{2\sin\theta}, \quad s = 2l(1-\cos\theta)$$

Variables

F	Force applied at the knee (perpendicular to the output)	N
θ	Link angle from the straight line	rad
l	Link length	m
P	Output force along the line of the links	N
P/F	Mechanical advantage	-
F_l	Force in each link	N
s	Output stroke left until the links are straight	m

Method and standards

Toggle force.

Assumptions and limits

- Symmetrical, frictionless, rigid links; quasi-static.

References

Equilibrium of a toggle joint

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/mechanical/statics-dynamics/toggle-mechanism-force

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.