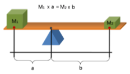
A **LEVER** is a a machine consisting of a beam or rigid rod pivoted at a fixed hinge, or fulcrum.

A balanced machine shows a situation where there is no movement, i.e. moments of two forces (torques) around a fulcrum are equal, i.e creating a balanced situation.



$$T_1 = M_1 a = M_2 b = T_2,$$

where M_1 is the input force to the lever and M_2 is the output force.

MECHANICAL WORK is a concept that measures what a force does when it works at a distance.
Work, a form of energy, is force times distance. Unit = Joule, calories, kilowatt-heures.
One Joule is equal to the energy expended (or work done) by a force of one newton through a distance of one metre.

POWER is the rate of doing work. It is equivalent to an amount of energy consumed per unit time, i.e. force times velocity.
Unit = joule per second (J/s), known as the watt in honour of James Watt, the eighteenth-century developer of the steam engine.
The power into and out of an ideal mechanism, here involving a lever, is the same.
Power is the product of force and velocity, so forces applied to points farther from the pivot must be less than when applied to points closer in.
As the lever pivots on the fulcrum, points farther from this pivot move faster than points closer to the pivot.

in terms of power:
F(a) * velocity(a) = F(b) * velocity(b)
MA = Fb/Fa = Va/Vb

in terms of work:
F(a) * distanced travelled(a)/time = F(b) * distance travelled(b)/time
F(a) * distance travelled (a) = F(b) * distance travelled (b)
MA = Fb/Fa = distance travelled (a) / distance travelled (b)

TORQUE or moment of force
A distance travelled can be calculated with the length of a lever arm:
lever arm = radius of the circle around which the movement is generated.
distance travelled = length of the arc that is covered during movement.

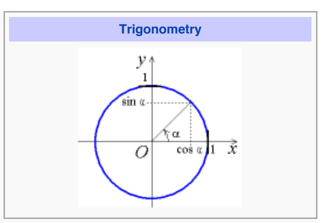
This is where angular distance, RADIANS and linear distance come in:

An angle's measurement in radians (angular distance) is numerically equal to the length of a corresponding arc of a unit circle
One radian is just under 57.3 degrees (when the arc length is equal to the radius)
A full circle's angle is **2π radians.**

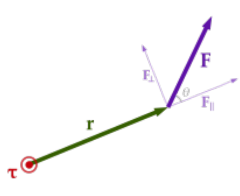
So, the distance travelled, which is the length of the arc, is numerically equal to the angular distance when measured in radians and in a unit circle of radius = 1.
When not in a unit circle**, Linear distance = radius (length of the lever) * angular distance (angle's measurement in radians)**

Again:
in terms of power: MA = Fb/Fa = Va/Vb
in terms of work: MA = Fb/Fa = linear distance (a)/linear distance (b)
in terms of work: MA = Fb/Fa = radius/lever arm (a) * angular distance (a) / radius/lever arm (b) * angular distance (b)

Torque (τ = tau) is the tendency of a force to rotate an object about an axis,[1] fulcrum, or pivot. It is a special case of moment of force where the force can move an object instead of, for example, bending it. Just as a force is a push or a pull, a torque can be thought of as a twist to an object. For example, a torque loosens or tightens a nut or bolt. The magnitude of torque depends on three quantities: the force applied, the length of the *lever arm* connecting the axis to the point of force application, and the angle between the force vector and the lever arm. Torque is calculated by decomposing a force into its components because only the perpendicular component will exert a torque.



sinus = length of Y component of a standard unit circle = circle with radius of 1 unit (my note: radius = 1 radian)
cosinus = length of X component; tangent = slope (pente) = Y component/X component



τ is defined as radius * force * sin (angle between force and lever axis)
τ = length of lever arm * perpendicular component of the force
there is no torque is the force is applied along the lever axis
Energy and torque appear similar, but they are entirely different concepts.

torque = radius * force, so force = torque/radius
power = (torque/radius) * (distance travelled/time) = (torque/radius) * (radius * angular speed * time/time)
power = torque * angular speed

in terms of torque:
torque (a) * angular speed (a) = torque (b) * angular speed (b)
MA = τb/τa = ωa/ωb

> **ω** = angular speed = angular distance/time (rad/sec)
> one circumference = 2π radians
> number of rotations = angular distance/2π

number of rotations/time = rotational speed = angular speed/2π
angular speed = rotational speed * 2π

power = torque * rotational speed * 2π

UNITS

Torque has dimension force times distance, and uses the unit *newton metre* (N·m) or the unit *joule per radian*.[8]
The SI unit for energy or work is the joule. It is dimensionally equivalent to a force of one newton acting over a distance of one metre, but it is not used for torque. Energy and torque are different concepts, so the practice of using different unit names (i.e., reserving newton metres for torque and using only joules for energy) helps avoid mistakes and misunderstandings.

Energy, Work: 1J = 1N * 1m
Torque (**τ**): 1Nm = 1N (at perpendicular angle) * 1m (length of lever)
Energy of this particular torque is force times distance = [1N at perpendicular angle] * [1m (length of lever) * angular distance in radians] = Nmrad
Torque (**τ**): 1 Joule/rad
And, the energy required by a torque of 1N to apply a full revolution of a lever machine with a lever of 1m is **2π Joules.**

Energy = torque * angular distance

BICYCLE GEARS

Bicycles: ideally, input power of cyclist is equal to output power of bicyle to the road. Input power (input torque * input angular speed) is converted into output power (output torque * output angular speed). So, by switching to larger sprocket in the back, i.e. output torque is higher, angular speed is lower, MA is larger.

Mechanical advantage in different gears of a bicycle. Note that even in low gear the MA of a bicycle is less than 1 because what we want is movement, not force on the wheel.

Another exemple:
crank radius: 7 inches, wheel diameter: 26 inches, radius = 13 inches, crank-wheel ratio = 7/13
if chainring has name number of teeth as sprocket, then,

$$MA = \frac{F_B}{F_A} = \frac{7}{13} = 0.54.$$

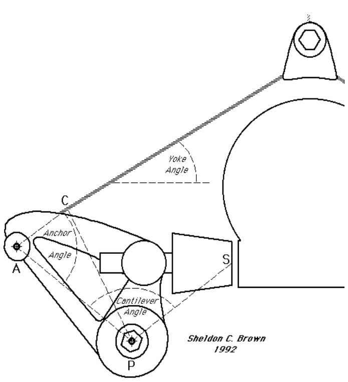
If chainrings: 28-52 and sprockets: 16-32, lowest speed ratio = 32/28 = 1.14 and highest speed ratio = 16/52 = 0.3

MA = F (output)/F (input) = Radius (input)/Radius (output) * number of sprocket teeth/number of chainring teeth
MA = crank/wheel ratio * rear gear/front gear

Lowest gear: MA .54 * 32/28 = 0.61
Highest gear: MA = .54 * 16/52 = .16

BICYCLE BRAKES

Power input = power output
(Force * distance) at input = (force * distance) at output
MA = τb/τa = ωa/ωb
MA = Fb/Fa = Vb/Va
MA = linear distance (b)/linear distance (a) = lever (b) * angular distance (b) / lever (a) * angular distance (a)



A brake with **high mechanical advantage will have a high ouput force, i.e. apply a lot of force to the brake shoe for a small amount of finger pressure on the brake lever but a long move of the hand lever**.

The first factor in MA is the brake lever itself. The lever's mechanical advantage is determined by the distance from the lever's pivot to the cable end, and by the effective length of the brake lever from its pivot to where the rider's fingers grip it. Typical mountain-bike type brake levers give a mechanical advantage of around 3 1/2, old-style **drop-bar** levers around 4, and "**æro**" drop-bar levers around 4 1/2. Levers for direct-pull ("V-type") brakes are around 2. My note: in theory, the MA of a brake lever would be with the ratio of distances covered by the lever and the cable head when the input force is applied.

The individual cantilever caliper's **mechanical advantage is the ratio between the pivot-cable distance (PC) and the pivot-shoe distance (PS)** . The pivot-cable distance (PC) is at its greatest when the **anchor angle** is 90 degrees, so that PC and PA are the same. Some authorities recommend adjusting the length of the transverse cable accordingly, but I believe that this is an over-simplification. With wide- and medium-profile cantilevers, the mechanical advantage of the cantilever unit increases as it travels inward, increasing as the brake shoes wear down. With narrow-profile cantilevers, the mechanical advantage tends to decrease as the cantilever travels inward. The mechanical advantage of a typical cantilever is generally between 1 and 2. Medium-profile cantis tend to have more of this type of mechanical advantage.

A larger contribution to the mechanical advantage of a well-adjusted cantilever brake, especially a low-profile one, comes from the transverse cable. The mechanical advantage is strictly determined by the "**yoke angle** ". The formula is: Mechanical Advantage = 1/sin yoke angle.

90 degree yoke = transverse cable, advantage = 1
0 degree yoke = vertical cable, advantage = infinite
30 degree yoke, advantage = 2
10 degree yoke, advantage = 5.76

Types of brakes from Jan Heine's article "Brakes 101"

Side-pull: work like set of pliers, the longer the upper arms are, the more MA, i.e. max force higher, but since overall lever is longer, needs more movement of brake lever for pads to reach rim. Risk of bottoming out. Thus pads must be set close to rim.

Dual-pivot: better return than in side-pull brakes. Thus, easier to set pads close to rim.

Cantilever brakes: pivots is on fork instead of on or near crown, less flex of lower arms but more flex of fork blades and seat stays when braking hard and this can change the angle of the pads when they hit the rim and then they squeal or they brake by locking suddenly on the rim.

Center-pull: have short lower arms like cantilevers, but pivot is now above the rim instead of below, which limits flex.

Disc brakes: brakes do not need to reach around the wheel, which limits flex of caliper arms. Smaller disc means shorter lever on the wheel, and thus brake must have very high mechanical advantage. So: 1) pads must be very close; 2) brakes work better in rain; 3) since more FB, more flex in rotor. Hydraulic have more power because less loss over transmission.

From Barnett, 34-3 and 34-8

Brake levers may be incompatible with some brake calipers. The distance from the center of the lever pivot to the center of the cable anchor determines the amount of inner wire that will be moved per degree of lever arm motion. My note: the longer the pivot-anchor distance is, the more cable is going to be moved per degree of lever moved and the quicker the pads are going to reach the rim. Greater maximum power, but less ability to modulate. This is what we do for MTB V-brake it seems. If the pivot-cable anchor distance is shorter, then less cable is moved per degree of movement of the lever, the slower the pads are going to reach the rim. Less maximum power, more modulation.

If pivot to cable-anchor distance is < or = to 25 mm, then this is high-leverage-ratio brake lever (i.e. lever has lot of leverage, lot's of modulation), do not use with V-brakes or disc-brakes.
If pivot to cable-anchor distance is = or > than 30 mm, then this is low-leverage-ratio brake lever (i.e. lever has less leverage, less modulation), use with V-brakes and disc-brakes.

Old short-pull lever, new direct pull ("V type") cantilever

Direct-pull cantilevers have a very high mechanical advantage, which makes them unsuitable for use with conventional levers. The excessive **mechanical advantage** of this combination will make it difficult to modulate the brake, and it may be all too easy to lock up the wheel. The lever feel will be very soft and mushy. The lever will travel too far before engaging the brake, and it may bottom out against the handlebar. Thus, the brake may be super-powerful at first, but as the brake shoes wear, the lever's bumping up against the handlebar will prevent full application. This is likely to be a particular problem in wet conditions.

New long-pull lever, old caliper or traditional cantilever

The reduced **mechanical advantage** will require unusually high hand strength to get barely adequate braking force. Paradoxically, the lever will *feel* very solid, the brake will engage with a very short amount of lever travel...but won't actually be squeezing very hard on the rim. Most **disc brakes** are designed for long-pull levers, but discs designated as "road" models are usually compatible with traditional short-pull levers.

New new: Sky told us that manufacturers are now designing specific combinations which will require our attention. For example, disc brakes with calipers specifically at medium MA.