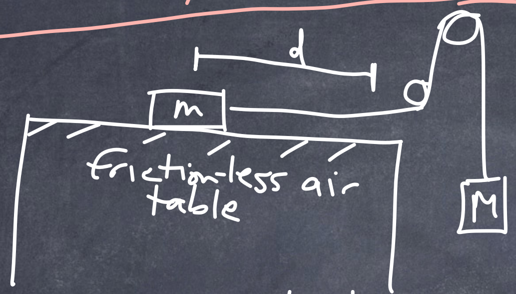
Lecture notes on course web page

PHY 117 HS2023

Week 2, Lecture 2
Sept. 27, 2023
Prof. Ben Kilminster

Extra: Yesterday, we had this problem:



What is acceleration of block m ?

Neglect mass of string
Neglect friction of pulleys

There are 2 ways to solve this problem.

1) we look at the whole system
2) we look at each block

1)

Consider that this is one object.
The total mass is $m+M$
It is accelerated by the force $F_g = Mg$

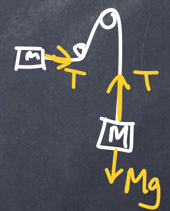
So $\Sigma F = \left(\text{mass of system}\right) a$

$$Mg = (M+m)\,a$$

$$a = \frac{M}{(M+m)} g$$

2) we look at the two blocks separately, and make equations for the forces on each.

block m: $\boxed{m} \rightarrow T$



There is only one force on m.
So $\Sigma F = ma$ ①
$\boxed{T = ma}$

block M:

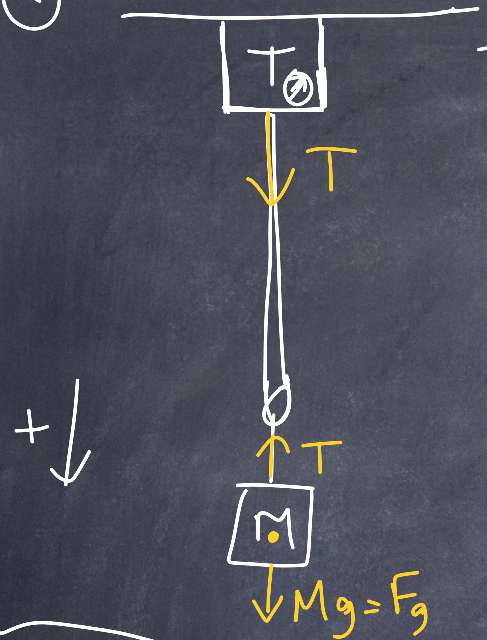
Here $\Sigma F = Ma$ ②
$\boxed{Mg - T = Ma}$

Adding ① + ②, we get $Mg - T + T = ma + Ma$

Notice that T cancels out

so $a = \left(\frac{M}{M+m}\right) g$

① Tension measurement



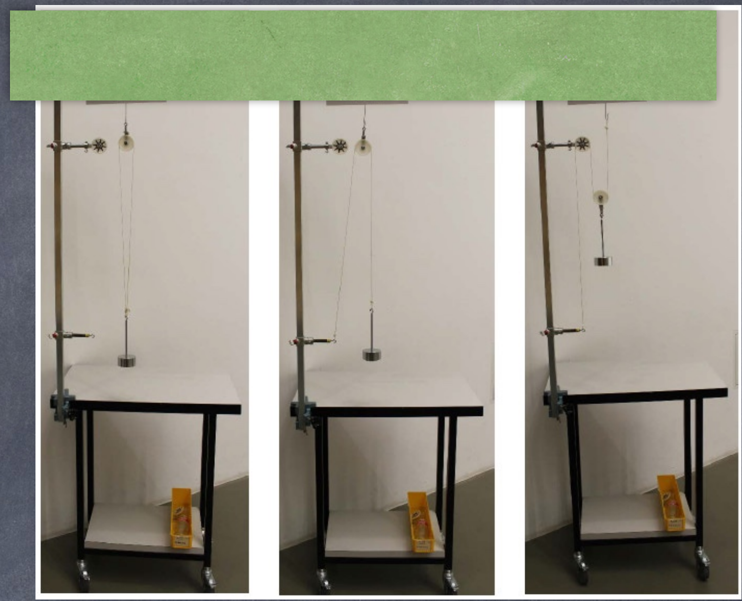
$M = 1\ \text{kg}$

$Mg = (1\ \text{kg})\left(10\ \frac{m}{s^2}\right) = 10\text{N}$

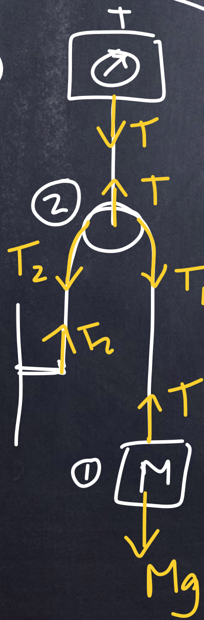
$\Sigma F = Mg - T = 0$

$T = Mg$

$= 10\text{N}$



②



$M = 1\text{kg} \rightarrow Mg = 10\text{N}$

At ①

$T_1 = Mg$ ①

At ②

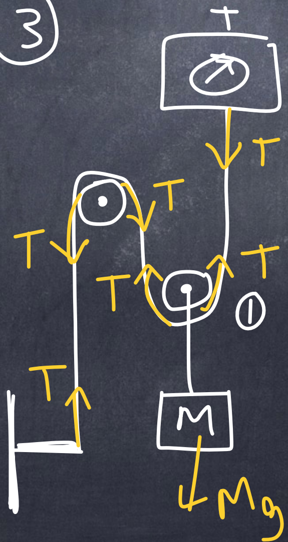
$T = T_1 + T_2$ ②

$T_1 = T_2 = Mg$

① → ②

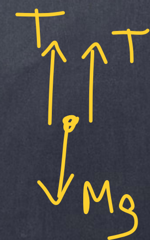
$T = 10\text{N} + 10\text{N} = 20\text{N}$

③



$M = 1\text{kg} \Rightarrow Mg = 10\text{N}$

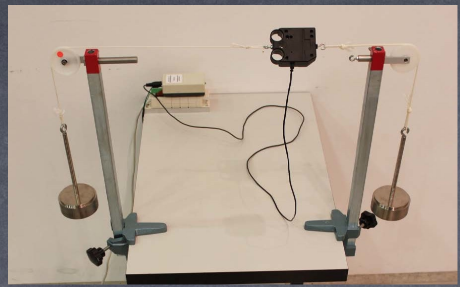
At ①:



$T + T = Mg$

$2T = Mg$

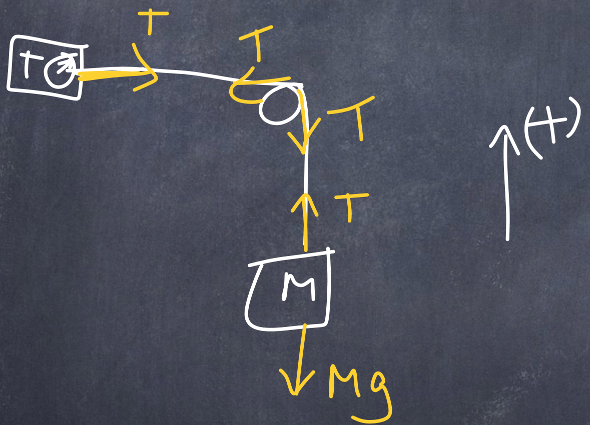
$T = \frac{Mg}{2} = 5\text{N}$



$M = 2\,kg$

$Mg = 20\,N$

④



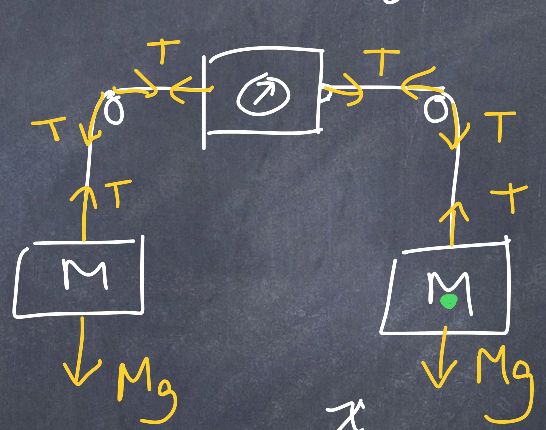
$$\Sigma F = 0 = T - Mg$$

$$T = Mg = 20\,N$$

$M = 2\,kg$

$Mg = 20\,N$

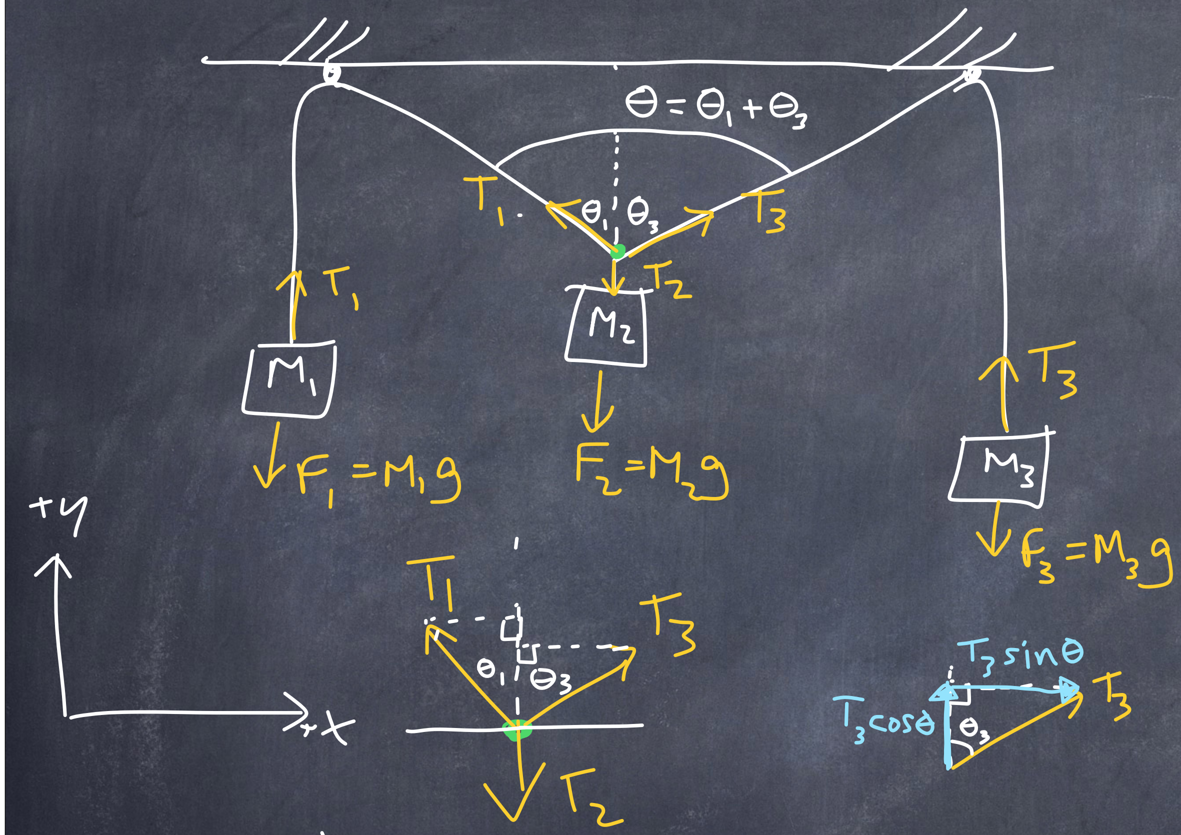
⑤

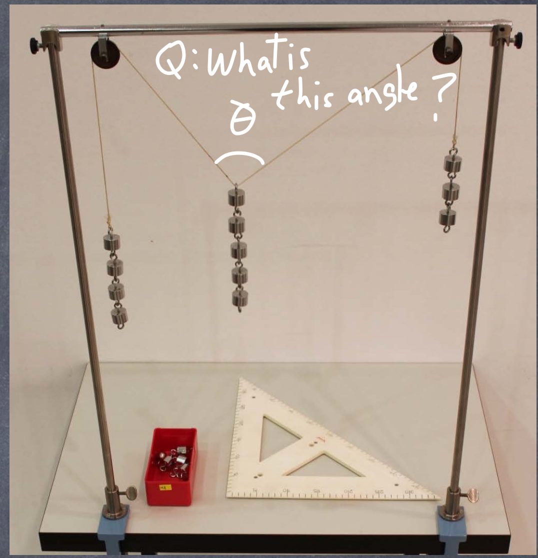


$$\Sigma F = T - Mg$$

$$T = Mg = 20N$$

In equilibrium → $\Sigma F = 0$





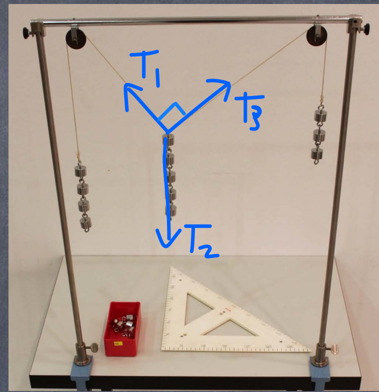
x direction: $-T_1 \sin\theta_1 + T_3 \sin\theta_3 = 0$

y direction: $-T_2 + T_1 \cos\theta_1 + T_3 \cos\theta_3 = 0$

If we knew T_1, T_2, T_3, then we could solve for $\theta_1 + \theta_3$.

$\theta = 180^\circ - \theta_1 - \theta_3$

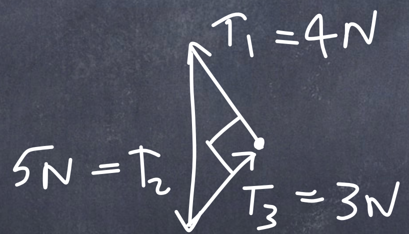
In our case, where $M_1 = 400g$, $M_2 = 500g$, $M_3 = 300g$
so $T_1 = 4N$, $T_2 = 5N$, $T_3 = 3N$



Not moving so $\Sigma F = 0$

It must be that
$$\overline{T_1} + \overline{T_2} + \overline{T_3} = 0$$

"end to tip" sum of vectors must end at same place that it starts.



we see that we have a 3-4-5 triangle, we know that this means we have a 90° angle (between T_1 + T_3)

What about the force on a Spring?

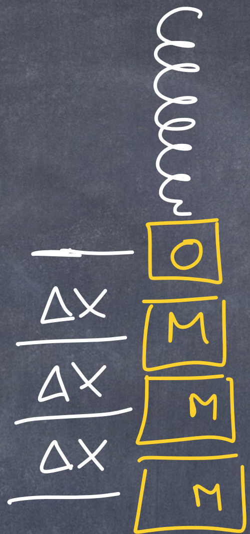
F_s : F_{spring}

$Mg = F_g$

(+)

$\sum F = 0 = F_g - F_s$

$F_g = F_s$



$F_s \propto \Delta X \Longrightarrow F_g = F_s$

$F_s = k \Delta X \qquad Mg = k \Delta X$

we can solve for

$$K = \frac{Mg}{\Delta X} = \frac{\cancel{2}Mg}{\cancel{2}\Delta X} = \frac{\cancel{3}Mg}{\cancel{3}\Delta X} = \frac{1N}{0.035m}$$

$Mg = 1N$, $\Delta X = 3.5cm = 0.035m$

what are the forces on the water?

At top:

$\uparrow (+)$

$F_{Bucket\ on\ water} = F_B$

$\downarrow F_c$ $\downarrow \bar{a}$

$\downarrow F_g = mg$

$\uparrow$ mass of the water

$$\Sigma F = ma \qquad \bar{a} = \frac{v^2}{r}$$

$$-F_B - F_g = ma$$

$$-F_B - F_g = \frac{m\bar{v}^2}{r} \Rightarrow F_B + F_g = \frac{mv^2}{r} \qquad F_B = \frac{mv^2}{r} \overset{(-)}{-} mg$$

$$\boxed{\frac{mv^2}{r} = F_c = \text{centripetal force}}$$

At bottom:

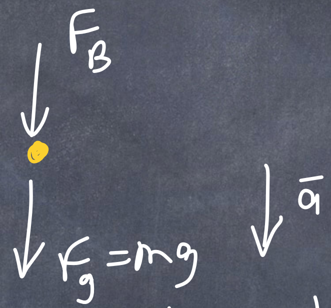
$F_B \uparrow \uparrow F_c$

$\downarrow F_g = mg$

$$\Sigma F = ma$$

$$F_B - F_g = \frac{mv^2}{r} \Rightarrow F_B = F_g \overset{(+)}{+} \frac{mv^2}{r}$$

what is the minimum speed (V_{min}) necessary to keep the water in the bucket?



we want to solve for the case when the velocity is so slow (V_{min}) that the water is weightless $\Rightarrow$ the bucket doesn't push into the water, $F_B = 0$

when $F_B = \frac{mv^2}{r} - mg = 0 \Rightarrow \frac{mv^2}{r} = mg \leftarrow \frac{\cancel{m}V_{min}^2}{r} = \cancel{m}g$

$v = \frac{x}{t}$

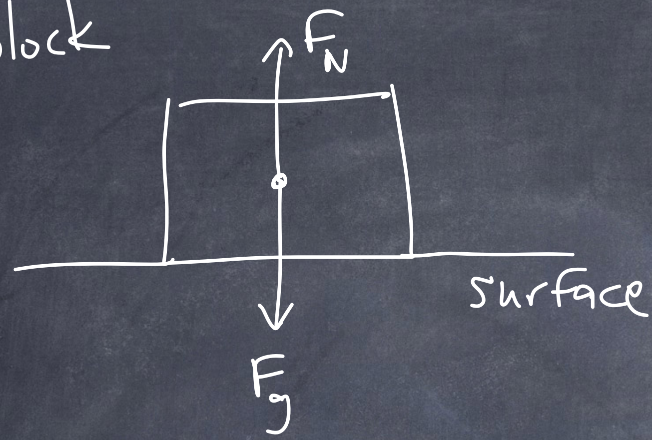
$\downarrow$

$t = \frac{x}{v}$

$V_{min} = \sqrt{rg}$

$T_{min} = \frac{2\pi r}{V_{min}} = \frac{2\pi r}{\sqrt{rg}} = \frac{2\pi (1m)}{\sqrt{(1m)(10\frac{m}{s^2})}} = 2s$

block

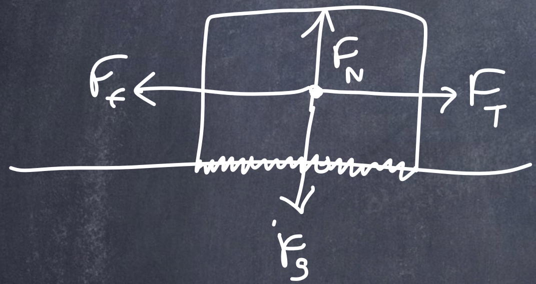


F_N: normal force pushing on the block by the surface.

F_N is always $\perp$ to the surface.
perpendicular

If $F_N = F_g$, then no acceleration.

we push the block:



F_T: force of thrust.

F_f: force of friction

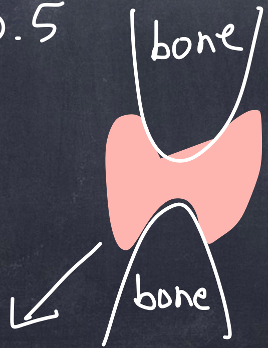
$$\boxed{F_f = \mu F_N}$$

μ: coefficient of friction
number between 0+1

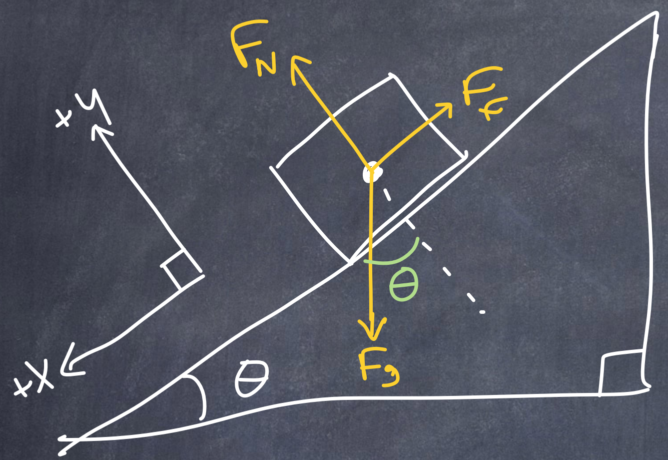
μ_s: static coefficient of friction

μ_k: kinetic coefficient of friction

2 materials	μ_k	μ_s
wood on wood	0.2	0.25-0.5
teflon on steel	0.04	0.04
ice on ice	0.03	0.1
steel on steel	0.57	0.74
synovial joint	0.003	0.01



Normal force, force of friction on an inclined plane.



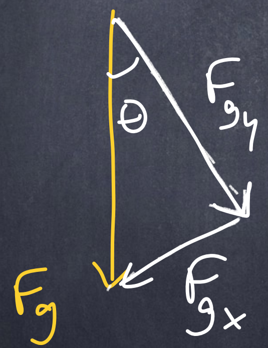
Notice: • normal force is perpendicular to the surface.

• friction force is parallel to the surface

• F_g points straight down.

$$F_f = \mu F_N$$

$$F_g = mg$$



$$F_{gy} = -mg\cos\theta$$

$$F_{gx} = +mg\sin\theta$$

check equations:

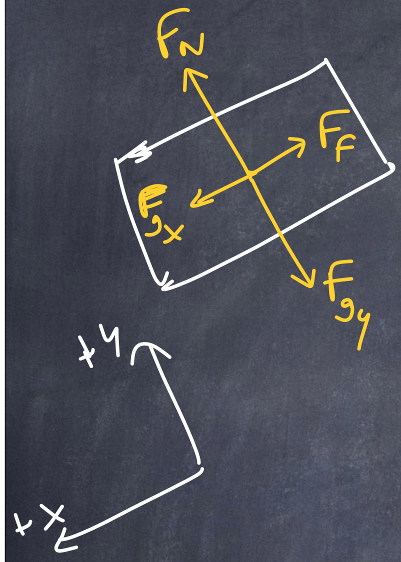
what if θ=0?

$$F_{gy} = -mg\,\overset{1}{\cancel{\cos(0^\circ)}}$$

$$F_{gy} = -mg = F_g$$

At equilibrium, $\sum F_y = F_N - F_{g_y} = 0$ $\quad F_N = F_{g_y} = mg\cos\theta$

$$\sum F_x = F_{g_x} - F_f = 0 \qquad F_f = F_{g_x} = mg\sin\theta$$



we know $F_f = \mu F_N = \mu mg\cos\theta$

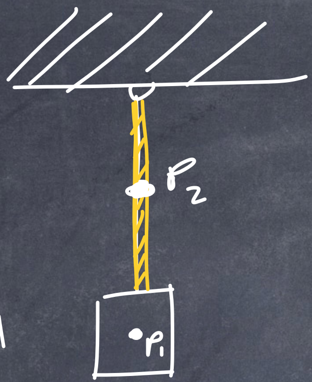
$$\cancel{mg}\sin\theta = \mu \cancel{mg}\cos\theta$$

$$\mu = \frac{\sin\theta}{\cos\theta} = \tan\theta$$

we can measure μ_s (or μ_k) by finding the $\tan\theta$, when the block starts (or keeps) moving.

Aside:

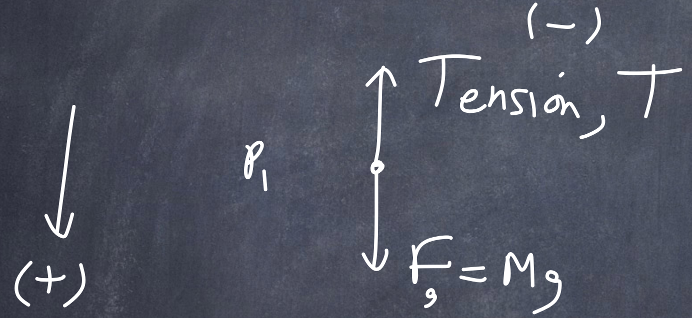
Exercise:



mass, M

A mass M hangs from a string to the ceiling.

Draw the forces acting at P_1.



If we use T and F_g as scalars, then we need to keep track of negative signs.

We state T is in (−) direction

$$\Sigma F = F_g - T = 0 = ma$$

and $T = F_g$

But we must specify the direction

$F_g = Mg$ in (+) direction

$T = Mg$ in (−) direction

If we use vectors for $\bar{F}_g$ and $\bar{T}$, then we don't need to explicitly put negative signs in our sum, $\Sigma \bar{F}$.

$$\Sigma \bar{F} = \bar{F}_g + \bar{T} = 0$$

then $\bar{T} = -\bar{F}_g$

since $\bar{F}_g = M\bar{g}$,

then $\bar{T} = -M\bar{g}$

In both cases F_g points down & T points up.

tg α
0.9
0.7
0.5