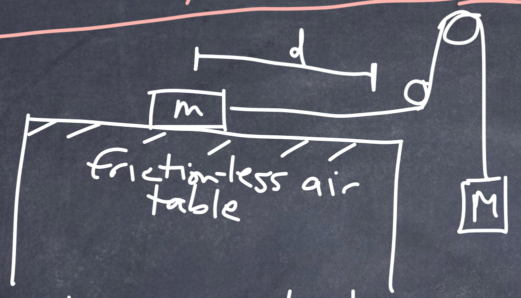
# PHY 117 HS2024

Week 2, Lecture 2
Sept. 25, 2024
Prof. Ben Kilminster

Extra: Yesterday, we had this problem:




Neglect mass of string
Neglect friction of pulleys

What is acceleration of block m ?

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 $F_g = Mg$

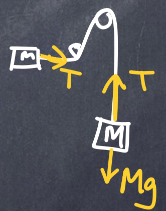
So $\Sigma F = (\text{mass of system})\, a$

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

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

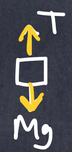
2) we look at the two blocks separately, and make equations for the forces on each.

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




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

block M:

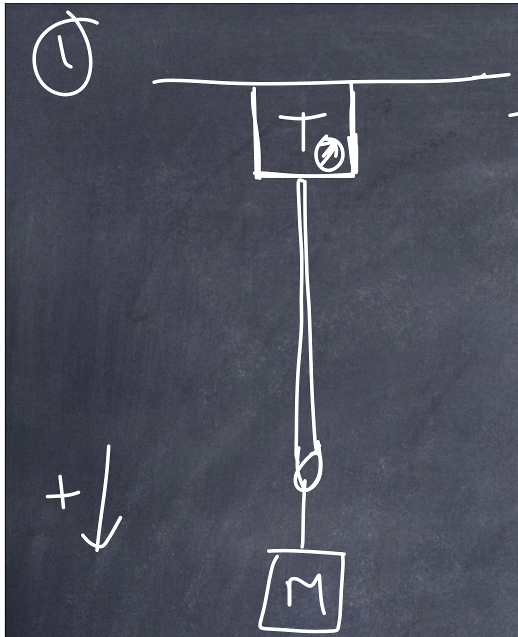



Here $\Sigma F = Ma$ ②
$$\boxed{Mg - T = Ma}$$

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

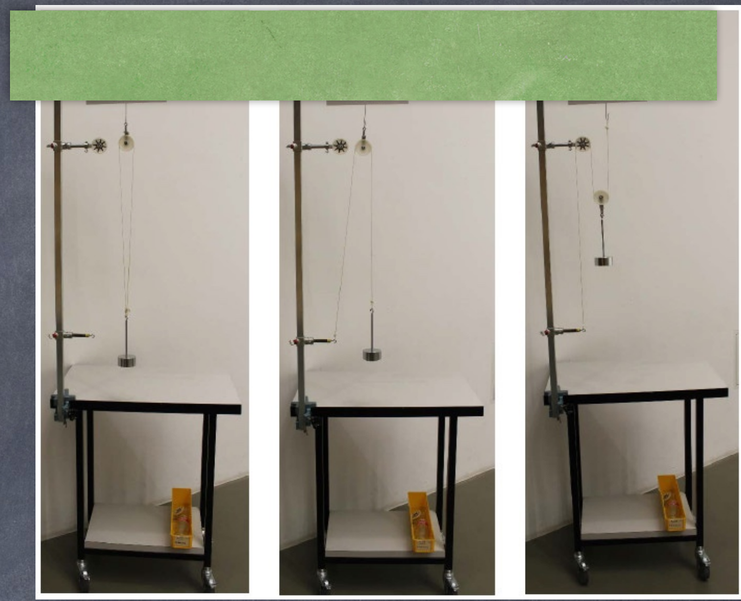
Notice that T cancels out

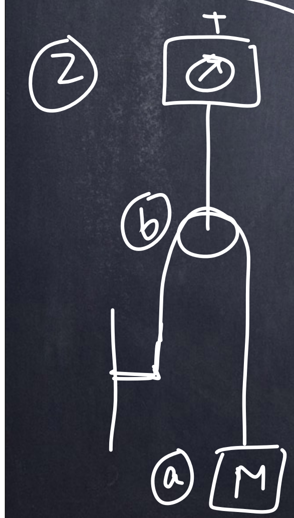
so $a = \left(\frac{M}{M+m}\right) g$

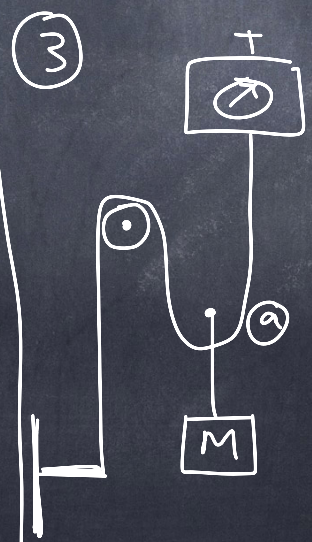



Tension measurement

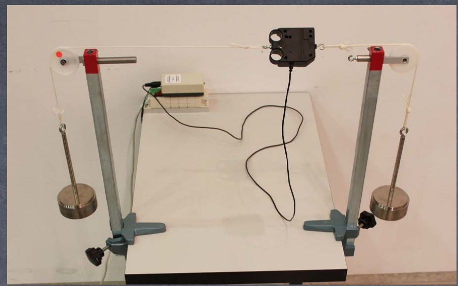
$M = 1$ kg





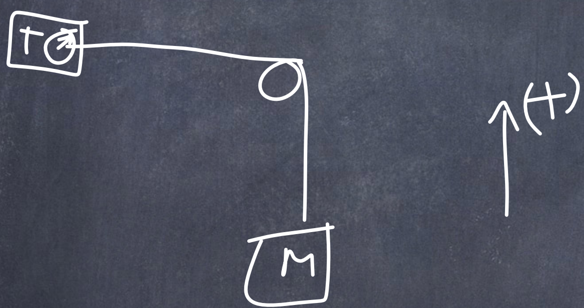




$M = 1\,kg \Rightarrow Mg = 10N$



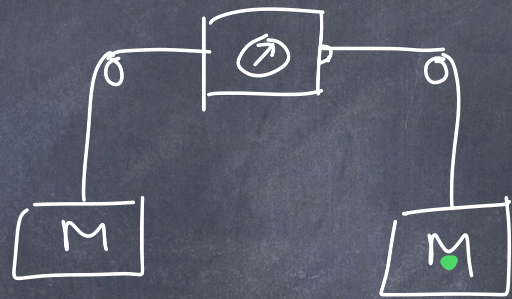
$M = 2kg$
$Mg = 20N$

4

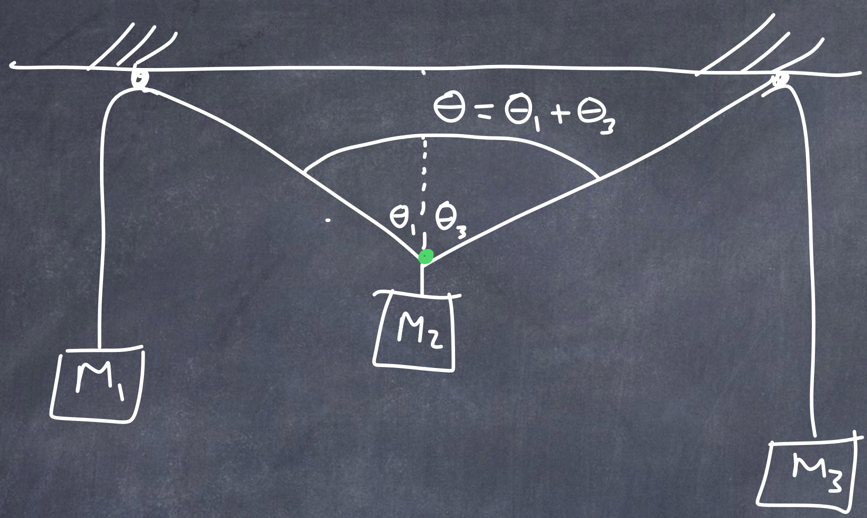


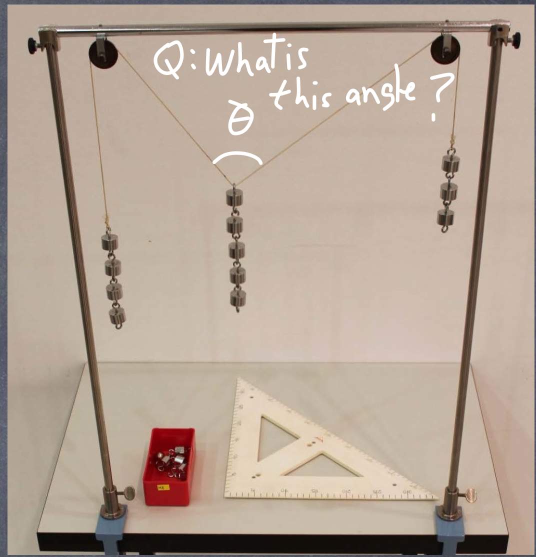

$M = 2kg$
$Mg = 20N$

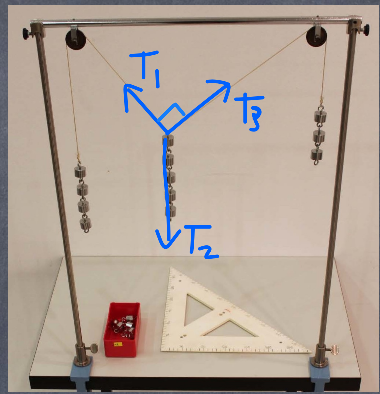
5



In equilibrium $\rightarrow$ $\Sigma F = 0$




T1
T3
T2

# What about the force on a spring?

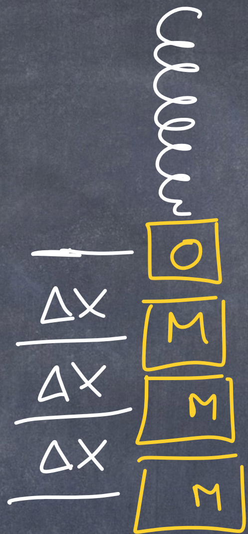
$F_s$ : $F_{spring}$

$Mg = F_g$

(+)

$$\Sigma F = 0 = F_g - F_s$$

$$F_g = F_s$$




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

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

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:


(+)

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

$F_c$ $\quad \bar{a}$

$F_g = mg$

mass of the water

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

$$-F_B - F_g = ma$$

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

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

At bottom:

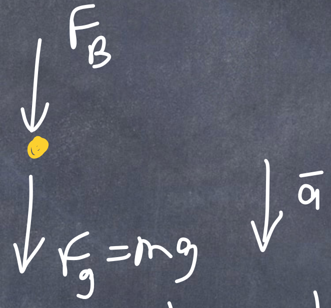

$F_B$ $F_c$

$F_g = mg$

$$\Sigma F = ma$$

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

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

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

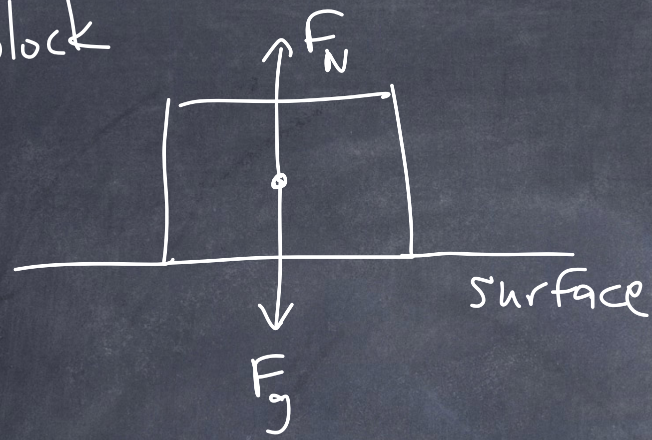
$\downarrow$

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

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

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

block



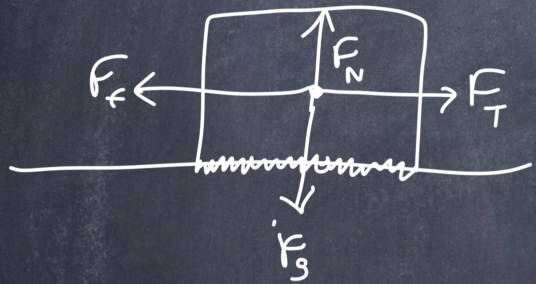

$F_N$: normal force pushing on the block by the surface.

$F_N$ 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

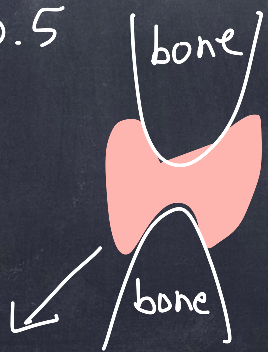
$$\boxed{F_f = \mu F_N}$$

$\mu$: coefficient of friction
number between 0+1

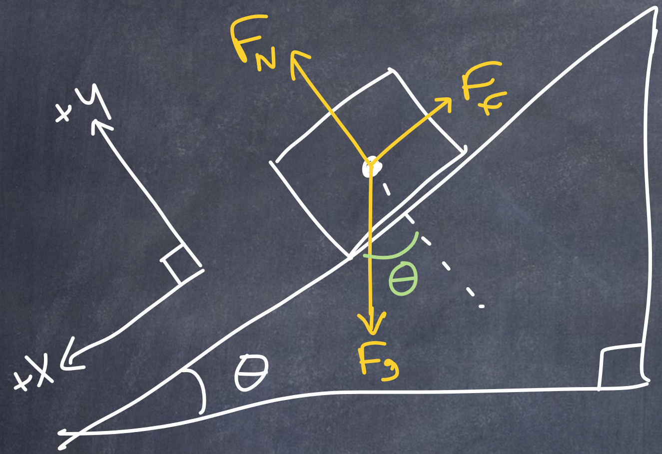
$\mu_s$: static coefficient of friction

$\mu_k$: kinetic coefficient of friction

| 2 materials | $\mu_k$ | $\mu_s$ |
|---|---|---|
| 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.



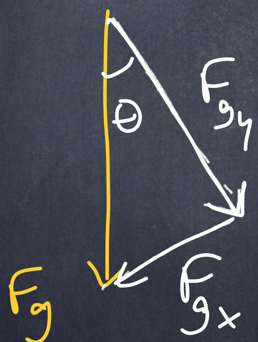

Notice: • normal force is perpendicular to the surface.

• 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:

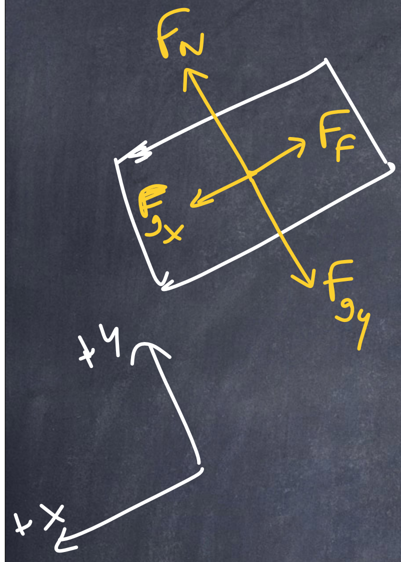
what if $\theta = 0$?

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

$F_{gy} = -mg = F_g$

At equilibrium,

$$\Sigma F_y = F_N - F_{g_y} = 0 \qquad F_N = F_{g_y} = mg\cos\theta$$




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

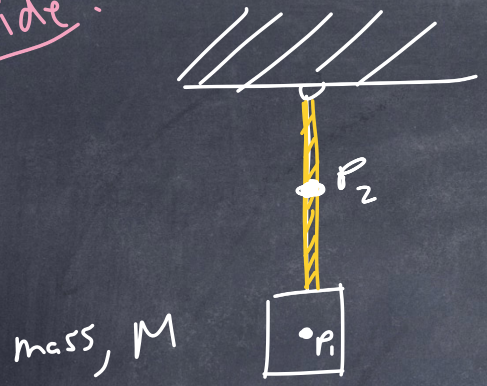
we know $F_f = \mu F_N = \mu mg\cos\theta$

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

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

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

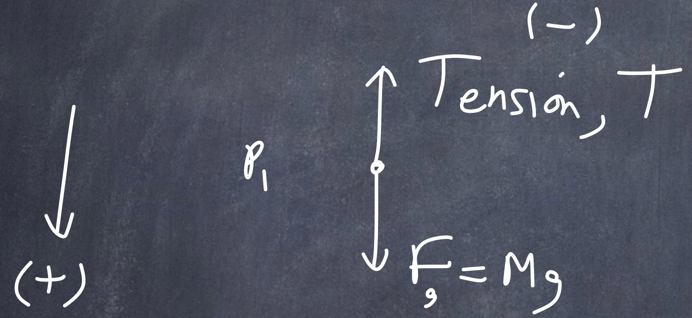
Aside:




Exercise:

A mass M hangs from a string to the ceiling.

Draw the forces acting at $P_1$.




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

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

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

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

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

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

We state T is in (−) direction

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

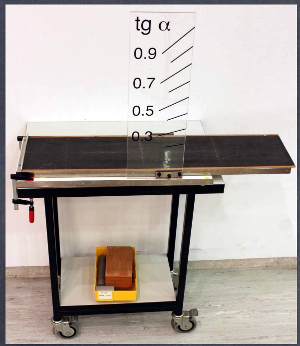
and $T = F_g$

But we must specify the direction

$F_g = Mg$ in (+) direction

$T = Mg$ in (−) direction

In both cases $F_g$ points down & T points up.


tg α
0.9
0.7
0.5