

PHY 117 HS2026

Balancing forces

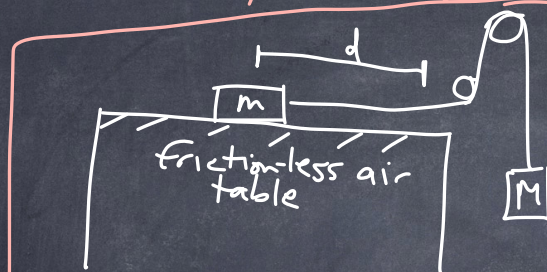
Week 2, Lecture 2
Sept. 23, 2026
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Prof. Florencia Canelli

Do the Week 2
Concepts quiz:
average completion time ~5min.

▼ Quiz 02

- ☐ Direction
- ☐ Average velocity
- ☐ Newton's laws I
- ☐ Newton's laws II
- ☐ Newton's laws III
- ☐ Newton's laws IV
- ☐ Equilibrium
- ☒ Forces

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



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

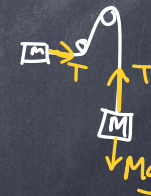
$$\text{So } \Sigma F = (\text{mass of system}) a$$

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

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

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

block m:
There is only one force on m.
So $\Sigma F = ma$ ①
 $T = ma$



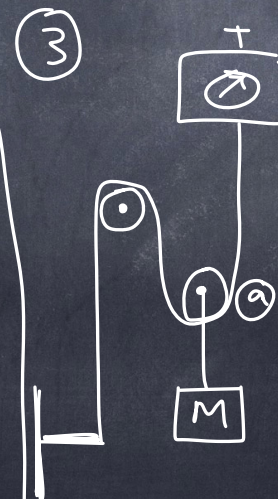
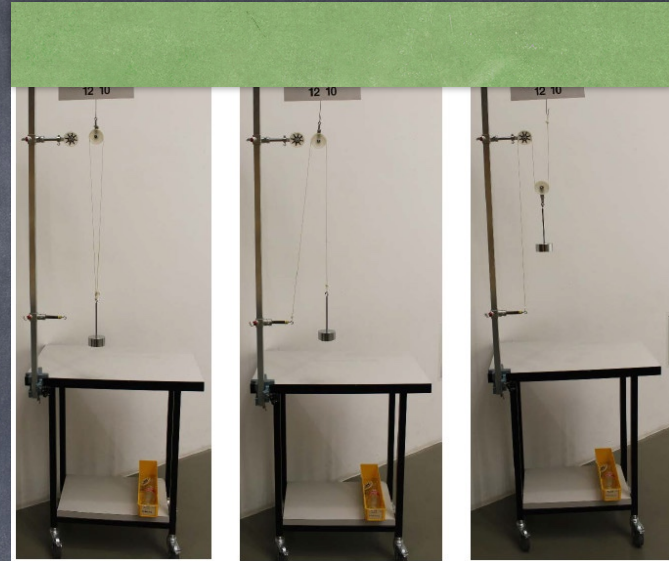
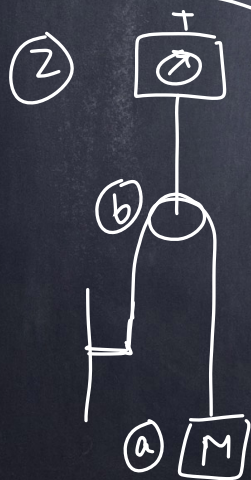
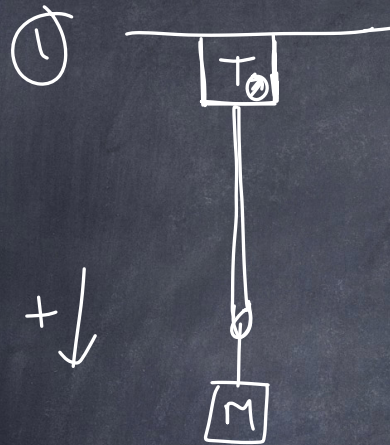
block M:
Here $\Sigma F = Ma$ ②
 $Mg - T = Ma$

Adding ① + ②, we get
so $a = \left(\frac{M}{M+m} \right) g$

$Mg - T + T = ma + Ma$
Notice that T cancels out.

Guess. that. Force!

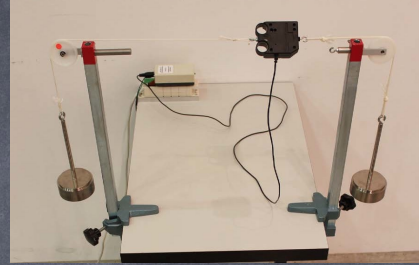
Guess. That. force !
 options : 5N, 10N, 20N
 $M = 1 \text{ kg}$
 $M_g = 10 \text{ N}$



Guess. That. Force!

$$M = 2\text{kg}$$
$$Mg = 20\text{N}$$

options: 5N
10N
20N



$$M = 2\text{kg}$$
$$Mg = 20\text{N}$$

④

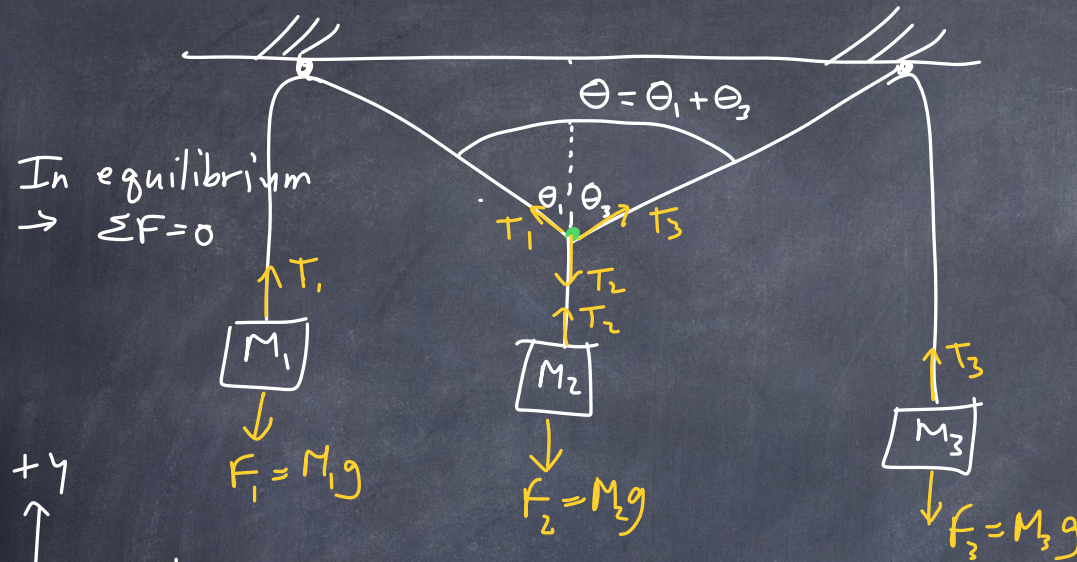


⑤

$$M = 2\text{kg}$$
$$Mg = 20\text{N}$$

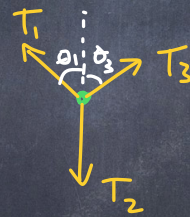


Static equilibrium: Guess that Angle!



we see:

$$\begin{aligned} T_1 &= M_1 g \\ T_2 &= M_2 g \\ T_3 &= M_3 g \end{aligned}$$



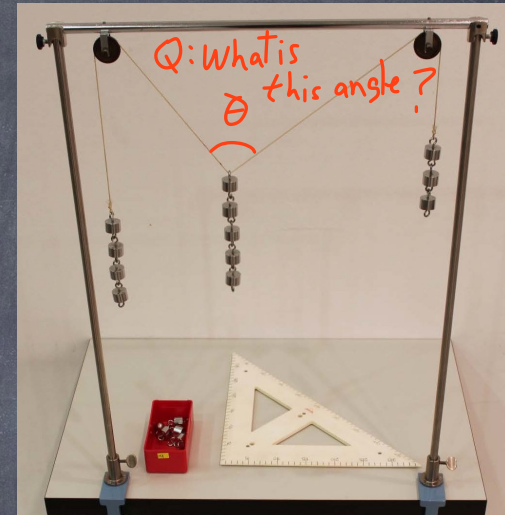
we can take $\vec{T}_1 + \vec{T}_3$ and decompose into $x + y$ components:



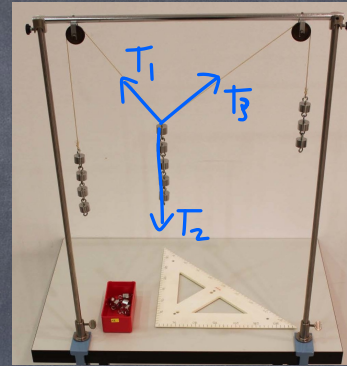
x direction: $\Sigma F_x = -T_1 \sin \theta_1 + T_3 \sin \theta_3 = 0$

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

If we knew T_1, T_2, T_3 , we could solve for $\theta_1 + \theta_3 \rightarrow$ get θ



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



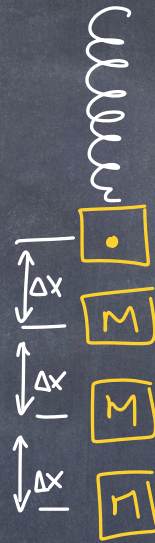
Let's now experimentally find the formula for the force on a spring.

(+)

$\downarrow$
 $\uparrow F_s$
 $\downarrow F_g$

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

$$F_g = F_s$$



we see that

$$Mg \rightarrow \Delta x$$

$$2Mg \rightarrow 2\Delta x$$

$$\vdots$$

$$\therefore \Delta x$$

we see : $F_s = Mg$ and $\Delta x \propto Mg$

therefore $\Rightarrow F_s \propto \Delta x$

Let's call "k" the constant of proportionality

we can solve for $k = \frac{Mg}{\Delta x} = \frac{2Mg}{2(\Delta x)} = \frac{3Mg}{3(\Delta x)}$

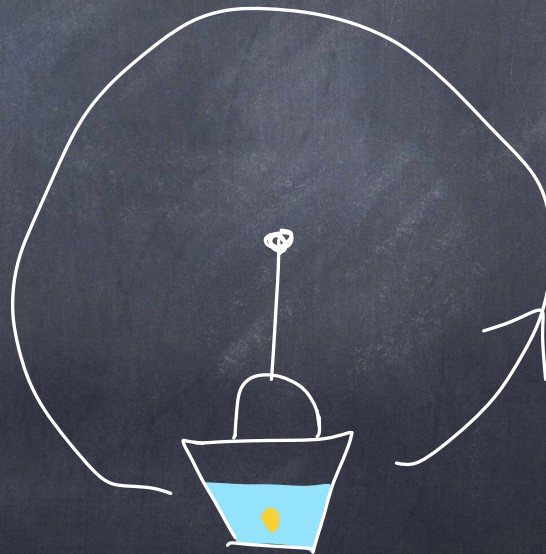


Now:
Forces in circular
motion

$$\Sigma F = m a_c$$

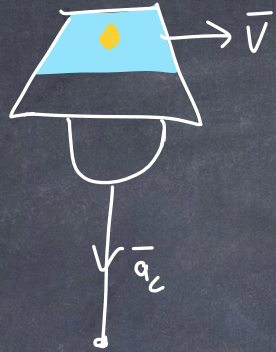
↑
this is
centripetal
acceleration

$$a_c = \frac{mv^2}{r}$$

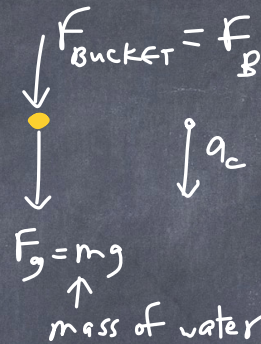


What are the forces on the water?

At top:



(+)



$$\Sigma F = ma_c$$

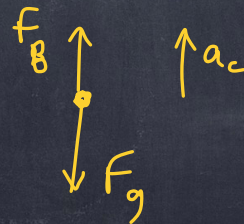
$$\bar{a}_c = -\frac{v^2}{r}$$

$$-F_B - F_g = ma_c$$

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

$$F_B = \frac{mv^2}{r} - mg$$

At bottom:

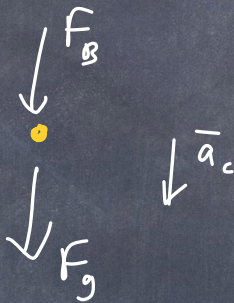


$$\Sigma F = ma_c$$

$$F_B - F_g = ma_c = \frac{mv^2}{r}$$

$$\Rightarrow F_B = \frac{mv^2}{r} + mg$$

What is the minimum speed ($v_{\min}$) necessary to keep the water in the bucket?



$$F_B = \frac{mv^2}{r} - mg$$



Note: Sometimes people refer to
a centripetal force, $F_c = ma_c = \frac{mv^2}{r}$

But realize that F_c is not
an additional force, it is this
part

not this part $\rightarrow \Sigma F = \overbrace{ma_c}^{\text{this part}}$
 $\Sigma F = F_c$

Note: Here we consider only constant angular speed
(no tangential acceleration)

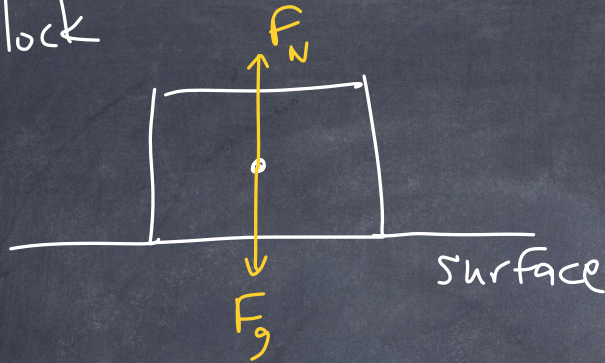
Now:

"Normal forces"

and

friction

block

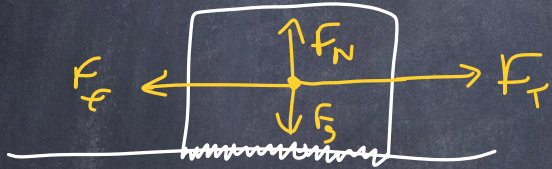


F_N : normal force pushing back on the block by the surface.

F_N is always $\perp$ to the surface

We see $F_N = F_g$, so no acceleration

we push or pull the block:



F_T : force of thrust

F_f : force of friction

$$F_f = \mu F_N$$

μ : coefficient of friction

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

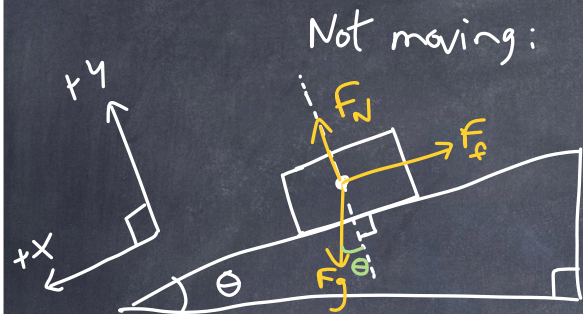




Measure Friction force with a spring



Consider block, mass M , on an incline, in equilibrium:



Notice: • normal force $\perp$ surface

• Friction force is $\parallel$ to surface

• F_g points straight down

Trick: Always draw sketch with a small θ . It helps to find θ .

Direction of forces:

F_N : $+\hat{y}$ direction

F_f : $-\hat{x}$ direction

F_g has $\hat{x} + \hat{y}$ components



Magnitude of forces:

$$F_g = Mg$$

$$F_f = \mu F_N$$

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

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

Trick:

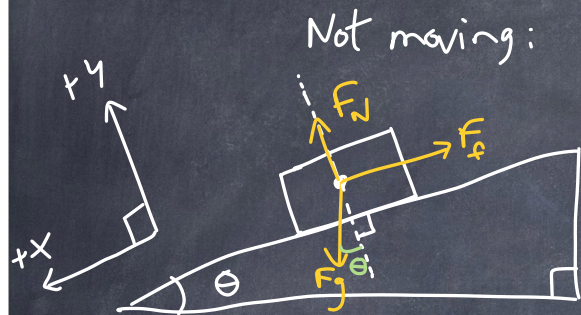
check equations

what if $\theta = 0$?

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

$$F_{gx} = mg \sin(0^\circ) = 0$$

At equilibrium, forces balance:



$$\Sigma F_y = 0 = F_N - F_{gy}$$

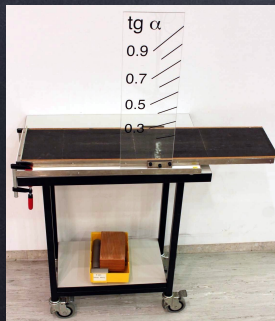
$$F_N = F_{gy} = mg \cos \theta$$

$$\Sigma F_x = 0 = F_{gx} - F_f$$

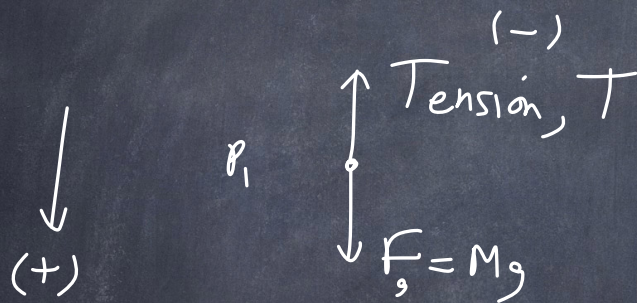
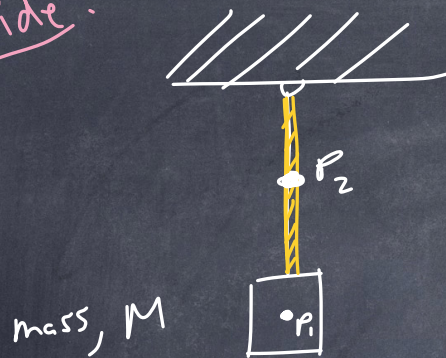
$$F_f = F_{gx} = mg \sin \theta$$

we also know: $F_f = \mu F_N$

$$mg \sin \theta = \mu (mg \cos \theta)$$



Aside:



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

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

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

Since $\vec{F}_g = M\vec{g}$,
then $\vec{T} = -M\vec{g}$

Exercise:

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

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

$$\text{and } T = F_g$$

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.

