

PHY 117 HS2026

Today:

Circular motion

Integral = area

Forces

Newton's 3 Laws

+ Survey results

Week 2, Lecture 1

Sept. 22, 2026

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Prof. Florencia Canelli

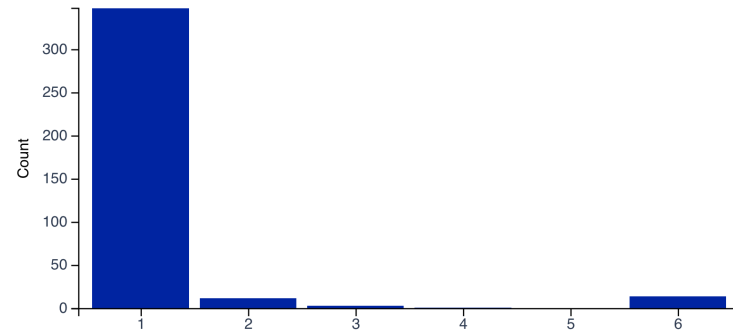
Survey results!

Who are you?

Number of participants

378

Where did you go to gymnasium / high school ?

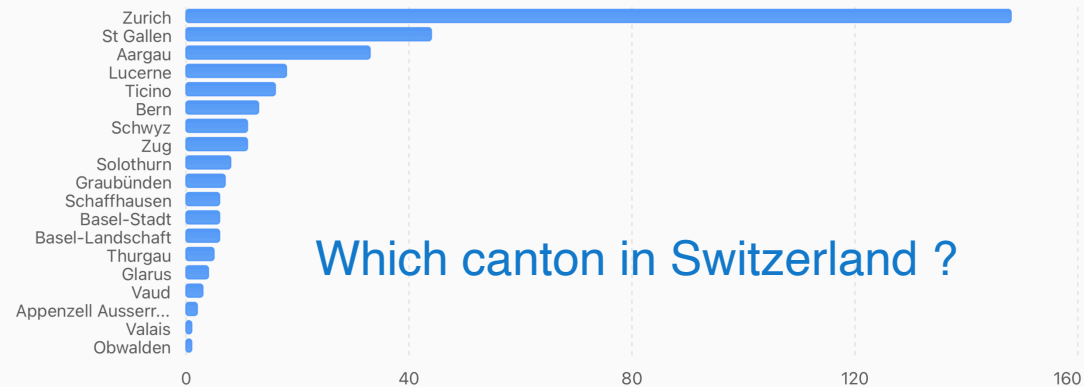


Legend

- 1: Switzerland
- 2: Germany
- 3: Austria
- 4: Italy
- 5: Liechtenstein
- 6: other

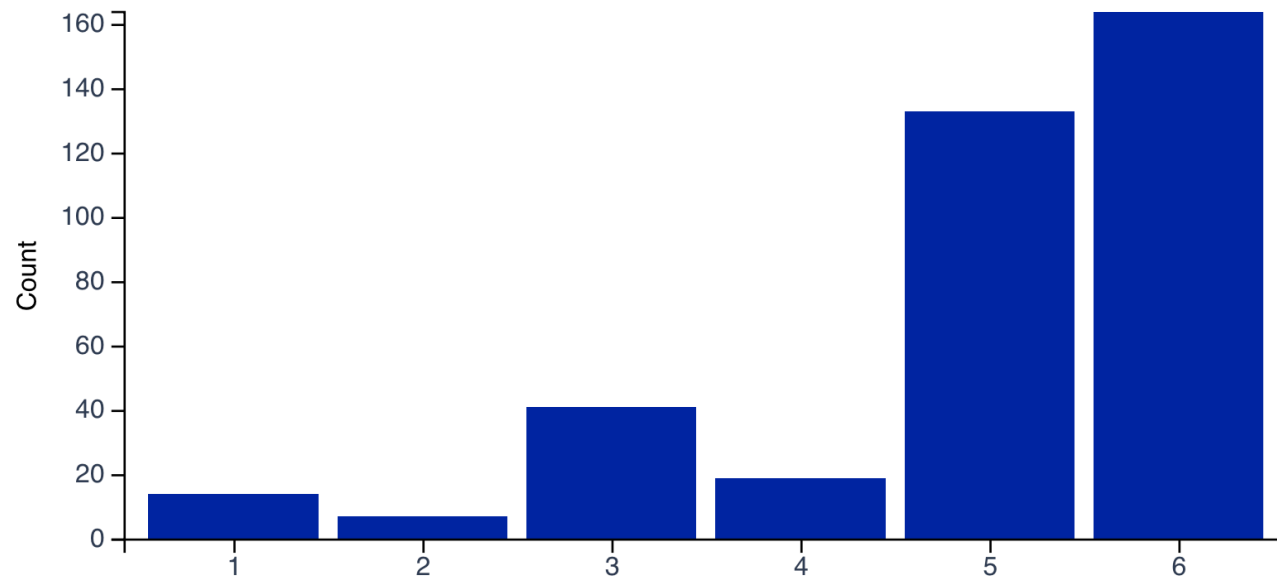
Other countries where students attended high school

- United Kingdom (3)
- Costa Rica (1)
- Georgia (1)
- France (1)
- Italy / Switzerland (1)
- Turkey (1)
- Thailand (1)
- Canada (1)
- Spain (1)
- Liechtenstein (1)
- Hungary (1)
- Egypt (1)



Which canton in Switzerland ?

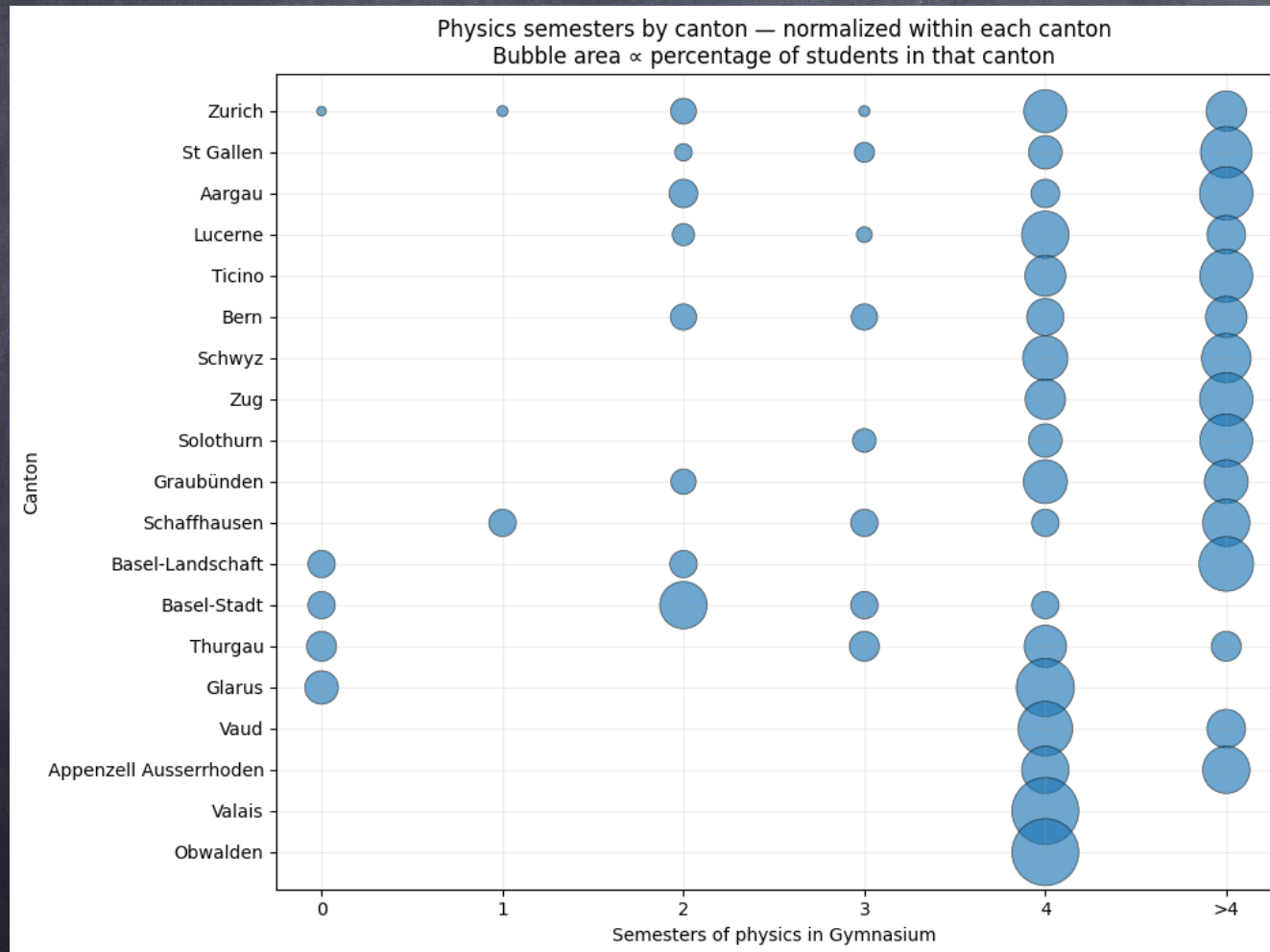
How many semesters of physics did you take in Gymnasium?



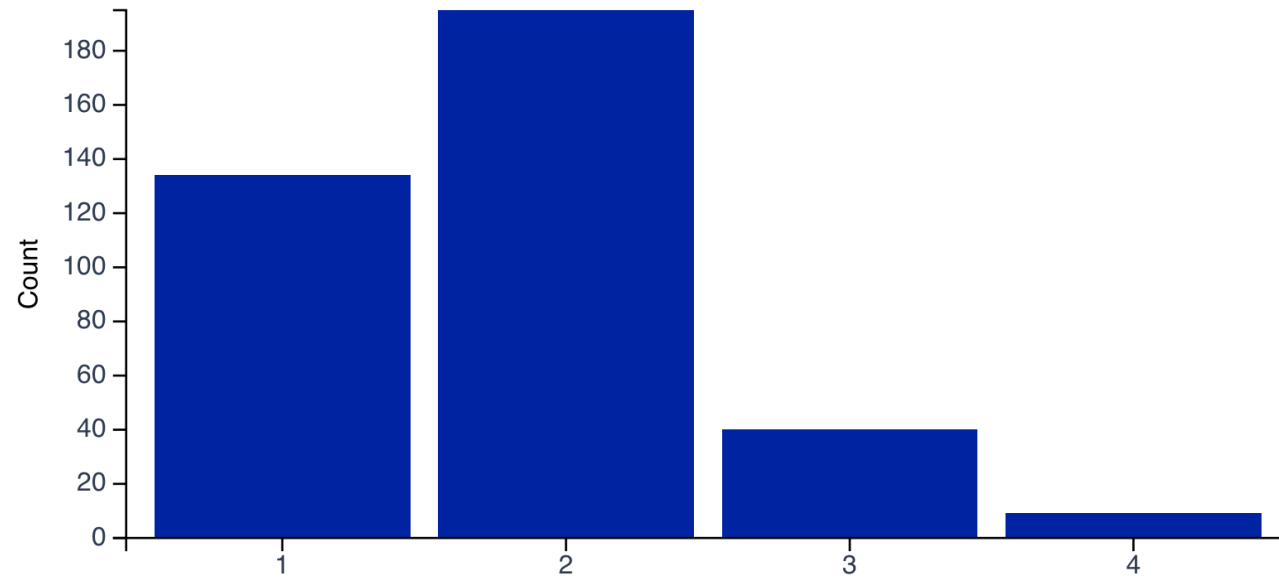
Legend

- 1:** non
- 2:** 1 semester
- 3:** 2 semester
- 4:** 3 semester
- 5:** 4 semester
- 6:** more than 4 semester

A little analysis ...



What is your major at UZH ?



Legend

- 1:** biology
- 2:** biomedicine
- 3:** biodiversity
- 4:** other

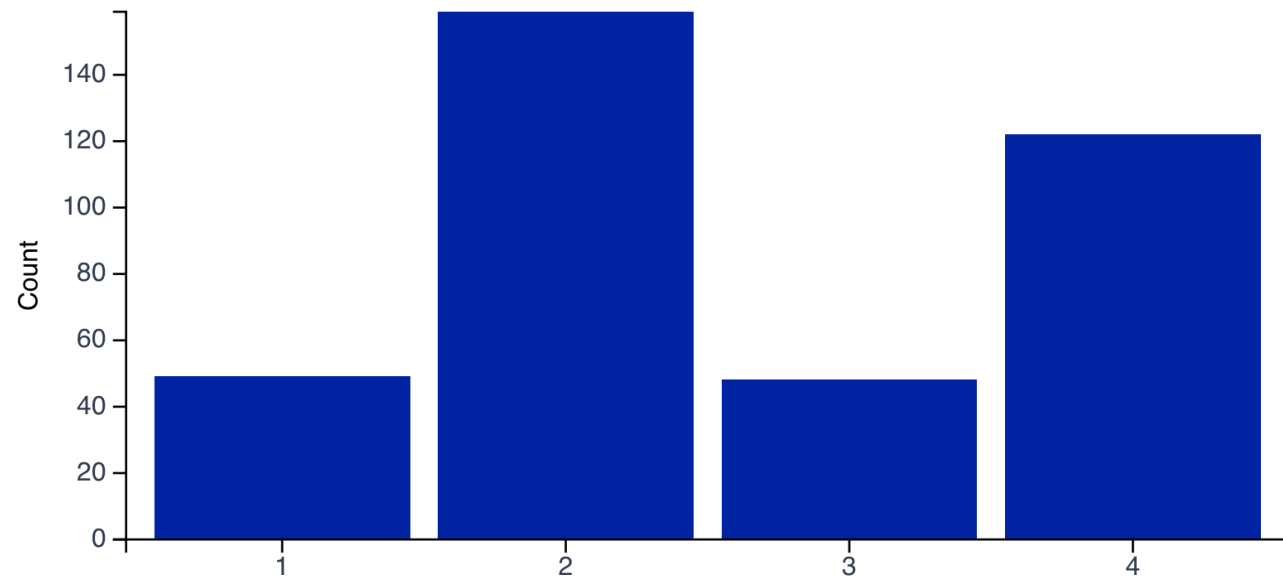
Other majors

- Psychology (3)
- Science Education / Teaching (1)
- Business Administration (1)
- Education Science (1)
- Archaeology (1)
- Political Science (1)
- Unspecified Master's student (1)
- No major specified (1)

Minors

- Astronomy & Astrobiology (13)
- Biomedicine (10)
- Business / Business Administration (10)
- Neuroinformatics (9)
- Biology (7)
- Bioinformatics (6)
- Earth System Sciences (6)
- Biodiversity (5)
- History, Politics & Society (5)
- Chemistry (4)
- Physics (4)
- Ethics (4)
- Sociology (3)
- Geography (3)
- Biochemistry (3)
- History (2)
- Law (2)
- Philosophy (2)
- German Language & Literature (2)
- Statistics / Probability (2)
- Communication & Media Studies (2)
- English / English Literature & Linguistics (2)
- Archaeology (2)
- French (2)
- Other individual minors (7)

Which statement fits you best ?



Legend

- 1:** I enjoy physics and I do quite well in it.
- 2:** I enjoy physics but I am not very good at it.
- 3:** I don't enjoy physics, but I do quite well in it.
- 4:** I don't enjoy physics, and I am not very good at it.

What students would particularly like to learn

- No specific topic / open to anything (13)
- Better general understanding of physics / build confidence or intuition (10)
- Applying formulas and solving physics problems correctly (5)
- Connections between physics and biology / biomedicine / other sciences (5)
- Electricity, circuits, electrical signalling & electromagnetism (4)
- Learning physics terminology / studying physics in English (4)
- "I just want to pass the class!" (3)
- Relativity (3)
- Learn the fundamentals / basics of physics (2)
- Astrophysics (2)
- MRI (2)
- Quantum physics / atomic & molecular physics (2)
- Hydrostatics / fluid dynamics (2)
- Experimental methods, uncertainties & measurement errors (1)
- Waves (1)
- Thermodynamics / diffusion / membrane physics (1)
- Radioactivity (1)
- Particle interactions (1)
- Physics applications to everyday life (1)
- Motivation, perseverance & discipline in learning physics (1)

"I'm a little
scared of it..."

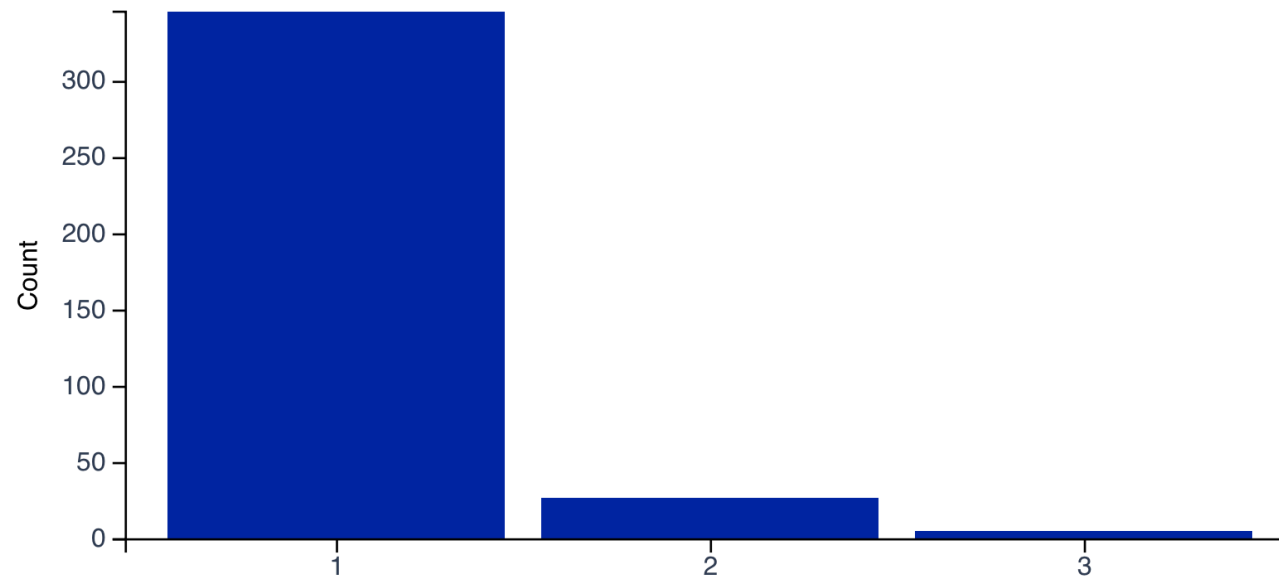
"I have no other choice..."

"I hope the lecturer
tries to make his
lectures
interesting"

"stuff useful
for general life"

"just want to pass bro"

Are you taking MAT 182 ?



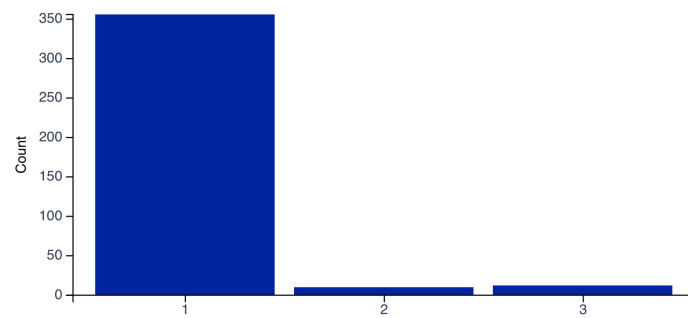
Legend

1: Yes

2: No

3: Not yet decided

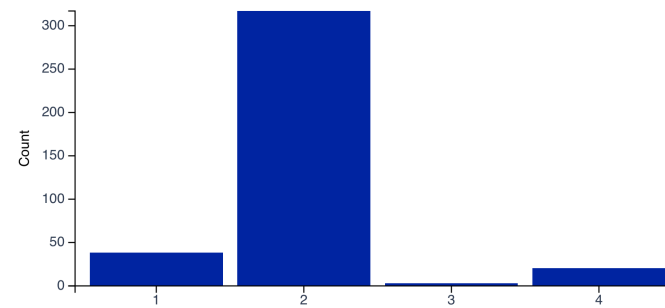
What is the derivative of x^3 with respect to x ?



Legend

- 1: $3x^2$
- 2: $2x^2$
- 3: $3x$

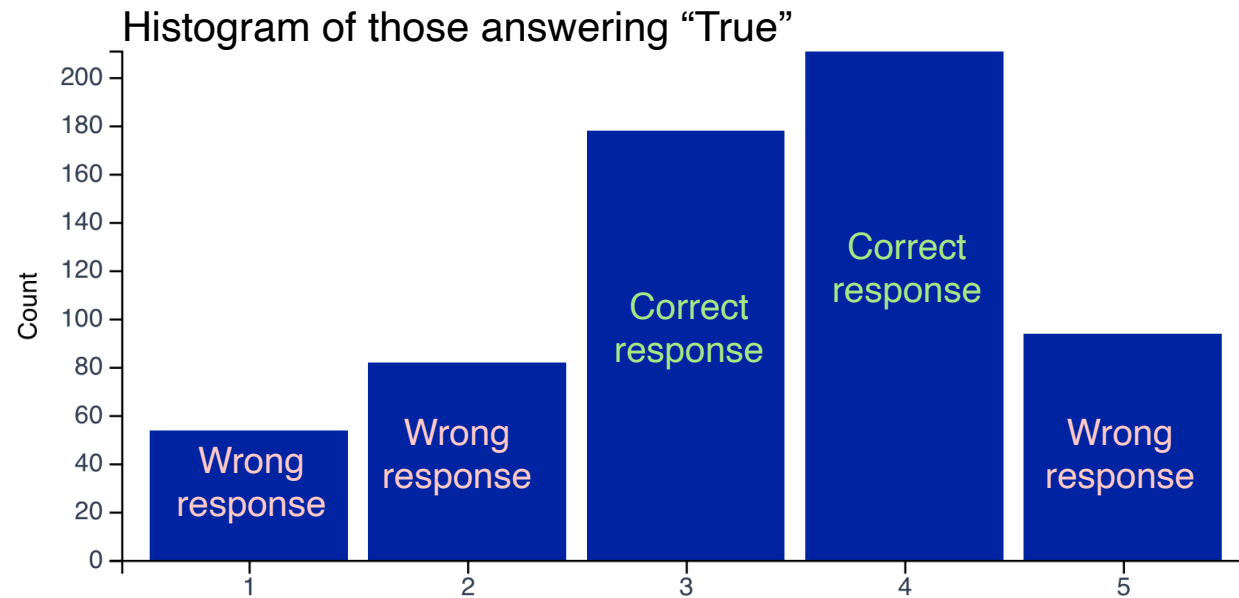
What is the integral of $3x^2$?



Legend

- 1: $6x$
- 2: x^3
- 3: 0
- 4: What's an integral?

Check all of the following statements that are true



Legend

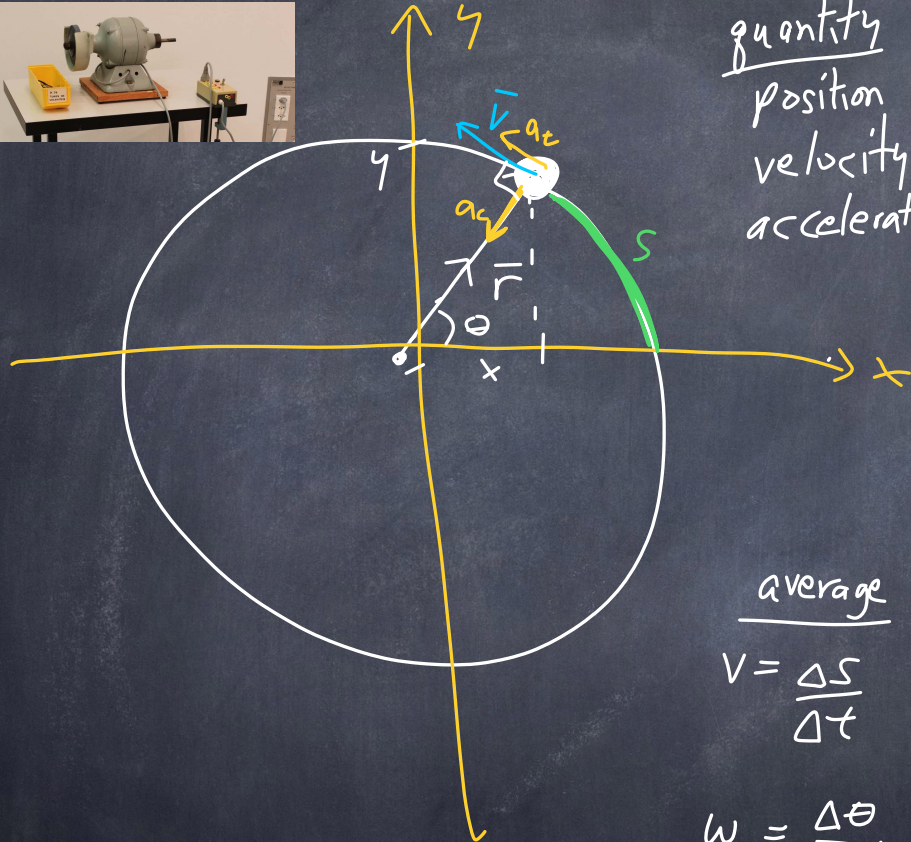
F
F
T
T
F

- 1:** A unit vector has a magnitude of zero.
- 2:** If a particle is moving at a constant velocity, the slope of distance vs. time will be zero.
- 3:** The position of a simple harmonic oscillator repeats in a time of $2\pi/\omega$.
- 4:** On the moon, a metal ball and a feather thrown from one astronaut to another would have the same parabolic motion.
- 5:** The acceleration of an object moving in a circle points in the same direction as the velocity.

And now back to our program...

Circular motion (in 2D)

at constant speed



quantity
position
velocity
acceleration

in terms
of distance

$$s [m]$$

$$v \left[\frac{m}{s} \right]$$

$$a_t \left[\frac{m}{s^2} \right]$$

in terms
of angles

$$\theta [1]$$

$$\omega \left[\frac{1}{s} \right]$$

$$\alpha \left[\frac{1}{s^2} \right]$$

relation

$$s = r\theta$$

$$v = r\omega$$

$$a_t = r\alpha$$

$$a_c = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = \omega^2 r$$

average

$$v = \frac{\Delta s}{\Delta t}$$

$$\omega = \frac{\Delta \theta}{\Delta t}$$

$$\alpha = \frac{\Delta \omega}{\Delta t}$$

instantaneous

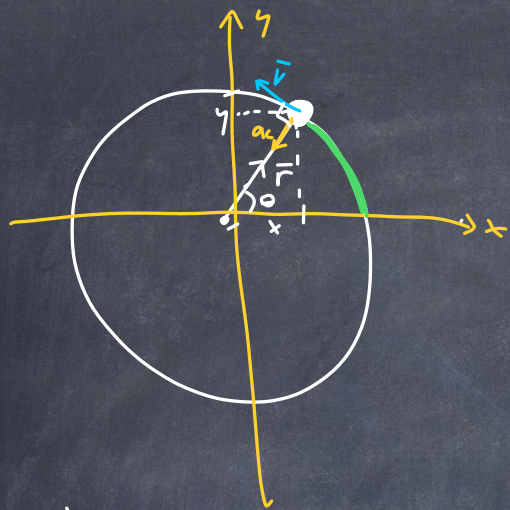
$$\rightarrow v = \frac{ds}{dt}$$

$$\rightarrow \frac{d\theta}{dt}$$

$$\rightarrow \frac{d\omega}{dt}$$

the number
is in
radians,
but this
is not a
unit
(like "%")

Equation of
angular motion for constant speed: $\theta = \theta_0 + \omega t$



We can determine x & y from trigonometry

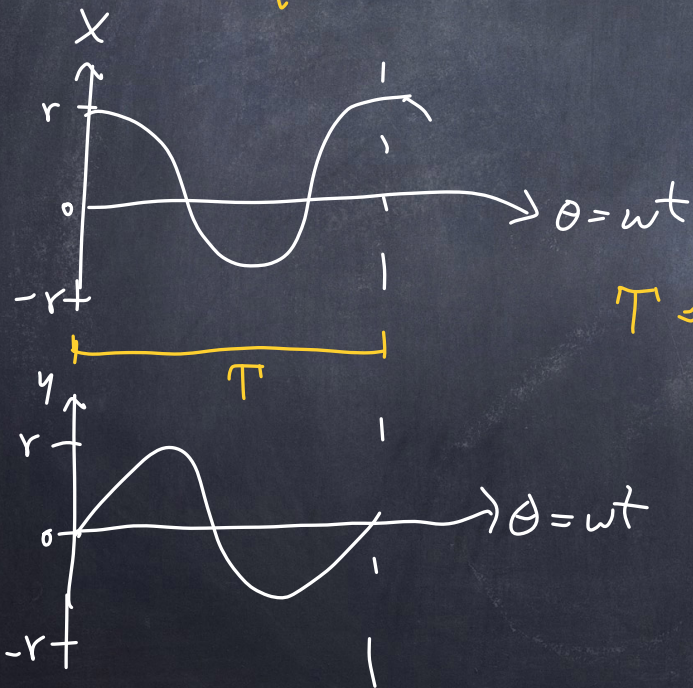
$$x = r \cos \theta$$

$$y = r \sin \theta$$

If speed is constant, then $\theta = \omega t$

$$x = r \cos(\omega t)$$

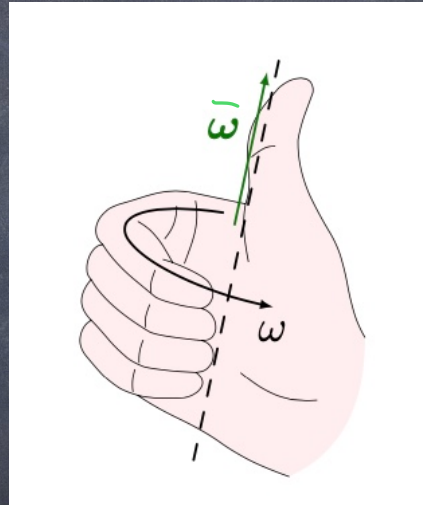
$$y = r \sin(\omega t)$$



$$T = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$$

Direction of $\omega + \bar{\omega}$ vector

right-hand rule

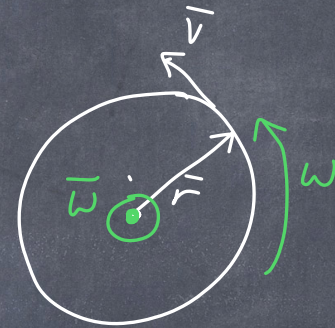


what if $\bar{\omega}$ is
changing? ($\alpha \neq 0$)

Direction of $\bar{\alpha}$

is in the same direction as $\bar{\omega}$
if angular speed is increasing

is in the opposite direction as $\bar{\omega}$
if angular speed is decreasing



⊙ arrow coming
towards you
(out of page)

⊗ arrow moving
away from you
(into page)

The concept of derivatives
is directly related to "slope"

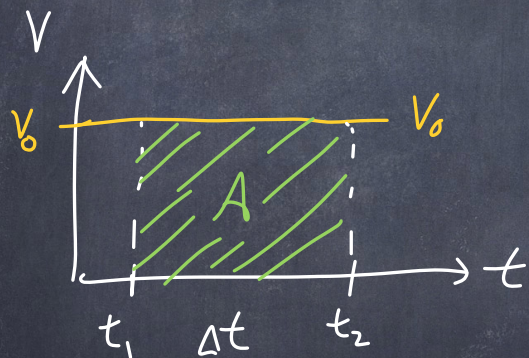
The concept of integrals
is directly related to "area"

Integrals $\leftrightarrow$ area

we have seen that $\frac{dv}{dt} = a \Rightarrow a$ is the slope of v vs. t

$\frac{dx}{dt} = v \Rightarrow v$ is the slope of x vs. t

Consider a particle moving at constant velocity:
 $v(t) = v_0 = \text{constant}$



we know that $v_0 = \frac{\Delta x}{\Delta t}$

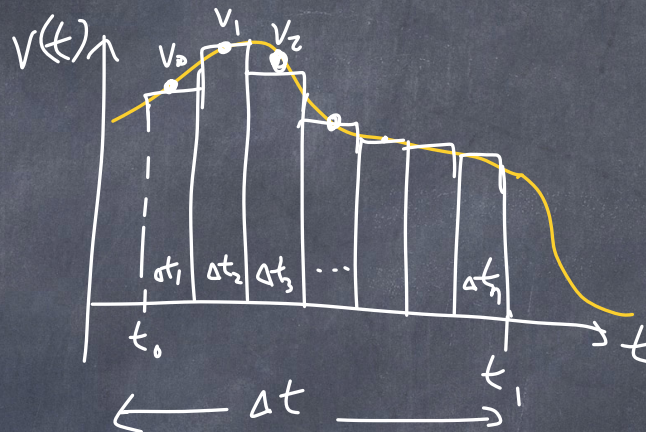
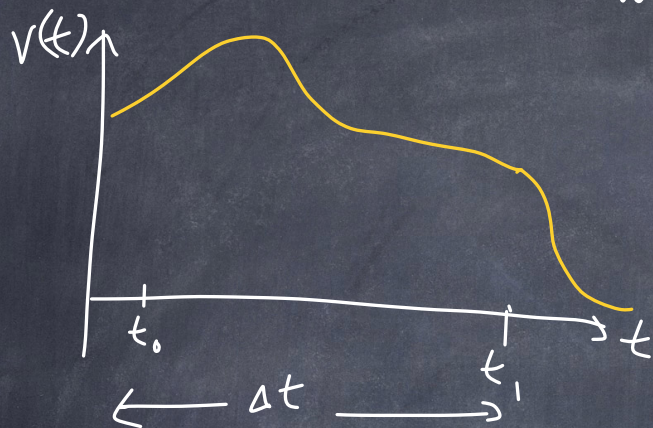
$$\Delta x = x_2 - x_1$$

$$\text{and } \Delta x = v_0 \Delta t$$

From the figure, we see that $v_0 \Delta t$ is the area of the rectangle $A = v_0 \Delta t$

So the change in position Δx is just the area under the v vs. t curve.

For a more complicated curve for v vs. t
we want to approximate Δx for this curve

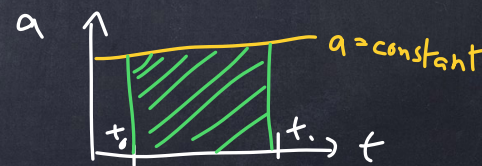


$$x_1 - x_0 = \Delta x = \sum_i^n v_i \Delta t_i$$

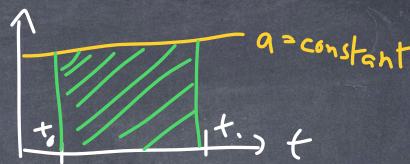
$$\Delta x = \lim_{\Delta t_i \rightarrow 0} \sum_i v_i \Delta t_i = \int_{t_0}^{t_1} v dt$$

so Δx = the integral of the curve (area of the curve)
of v vs. t from t_0 to t_1

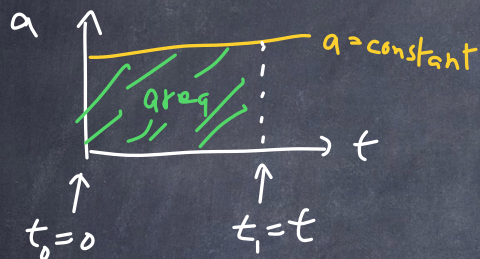
Likewise, $\Delta V = \lim_{\Delta t_i \rightarrow 0} \sum_i a_i \Delta t = \int_{t_0}^{t_1} a dt$



Likewise, $\Delta V = \lim_{\Delta t_i \rightarrow 0} \sum_i a_i \Delta t = \int_{t_0}^{t_1} a \, dt$

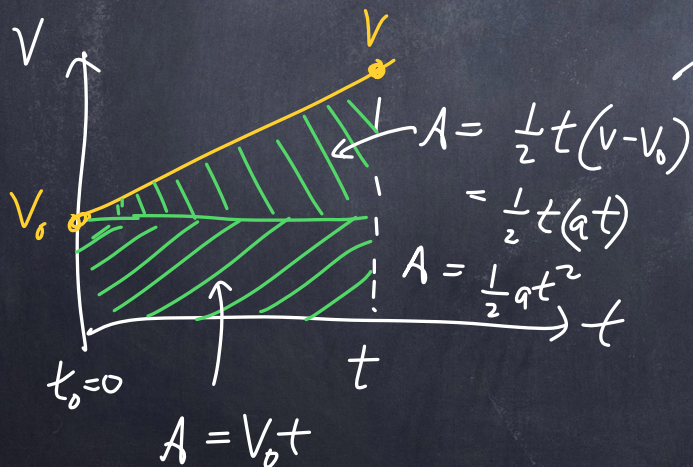


Assuming constant acceleration, what are formulas for $V = V(t)$ and $x = x(t)$?



$$\Delta V = V - V_0 = \int_{t_0=0}^t a \, dt = \left[at \right]_0^t = at - 0 = at$$

$$\Delta V = V - V_0 = at \Rightarrow \boxed{V = V_0 + at}$$



$$\Delta x = x - x_0 = \int_{t_0=0}^t v \, dt = \int_{t_0=0}^t (V_0 + at) \, dt$$

$$x - x_0 = \left[V_0 t + \frac{1}{2} at^2 \right]_0^t = V_0 t + \frac{1}{2} at^2$$

$$x - x_0 = V_0 t + \frac{1}{2} at^2$$

$$\boxed{x = x_0 + V_0 t + \frac{1}{2} at^2}$$

$$\text{So } \Delta x = x - x_0 = v_0 t + \frac{1}{2} a t^2$$

Notice: by understanding that $\Delta v = a \Delta t$ + $\Delta x = v \Delta t$,
we can derive eq. ② + ⑤ from week 1, lecture 2.

New topic: Forces

Forces:

A force is something that pushes or pulls an object.

One of the most common forces is "weight", which comes from gravity.

$$\text{weight} = F_g = \text{force of gravity} = \vec{F} = m\vec{g}$$

$\vec{g}$ points to the center of the earth

$\vec{g} = 9.81 \frac{\text{m}}{\text{s}^2}$
on earth



$$\vec{F}_g = m\vec{g}$$

Any two masses have a force between them:



$$F_g = G \frac{m_1 m_2}{r^2}$$

So g is related to G :

$$F_g = mg \Rightarrow g = \frac{G m_{\text{earth}}}{r_{\text{earth}}^2}$$

$$G = 6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}$$

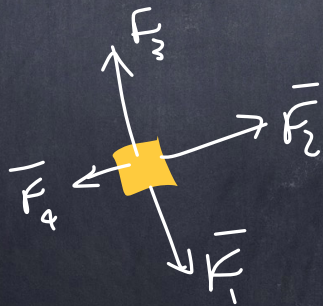
G is the universal gravitation constant

Forces are vectors, and can be added.

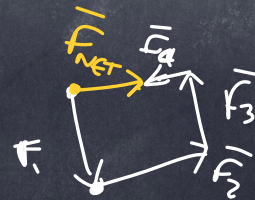
$$\sum_i \vec{F}_i = \vec{F}_{\text{TOT}} = \vec{F}_{\text{NET}}$$

If $\vec{F}_{\text{TOT}} = 0$, then there
is no net force;
we have equilibrium.

What about this case?



We can visualize $\vec{F}_{\text{NET}}$
with "Tail to tip" method

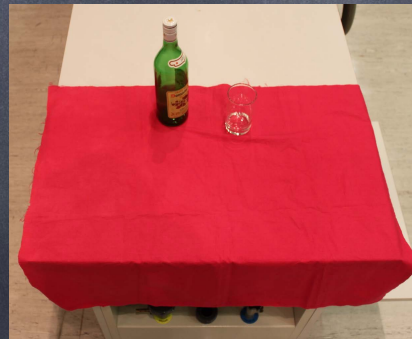
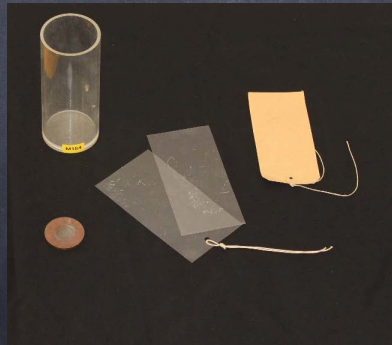


Newton's three laws for forces:

Law of inertia:

1) An object will remain at rest, or continue to move in a straight line, unless acted upon by a "net" force.

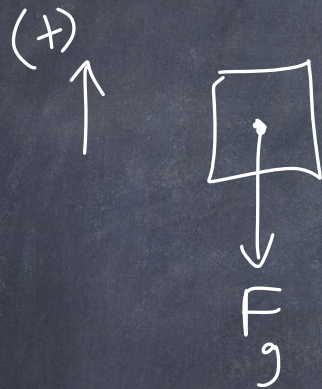
↑
non-zero



Second
Law:

2) A net force will cause an object to accelerate according to $\Sigma \vec{F} = m\vec{a}$

A common example is a falling object.



$$\Sigma \vec{F} = m\vec{a}$$

$$\Sigma \vec{F} = -\vec{F}_g = \cancel{m}\vec{g} = \cancel{m}\vec{a}$$

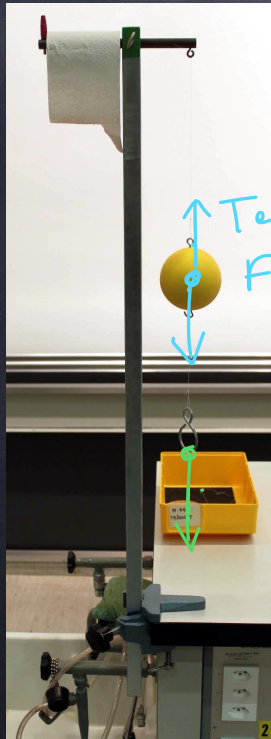
$$\text{so } \vec{a} = \vec{g}$$

Tests of Newton's first and second laws:

pull quickly : break bottom string (1st law)

→ ball provides inertia

→ top string doesn't feel F_{pull}



pull slowly : breaks top string

bottom string only feels F_{pull}
top string feels $F_{pull} + F_g = mg$

$\bar{F}_{pull}$ ↓ F_{pull}

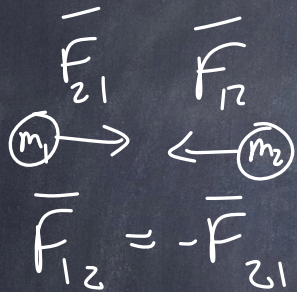
Summary:

pull it fast : first law

pull it slow : second law

Newton's third law:

3) when one object exerts a force on a second object, the second object exerts a force, equal in magnitude, but opposite in direction, on the first object.

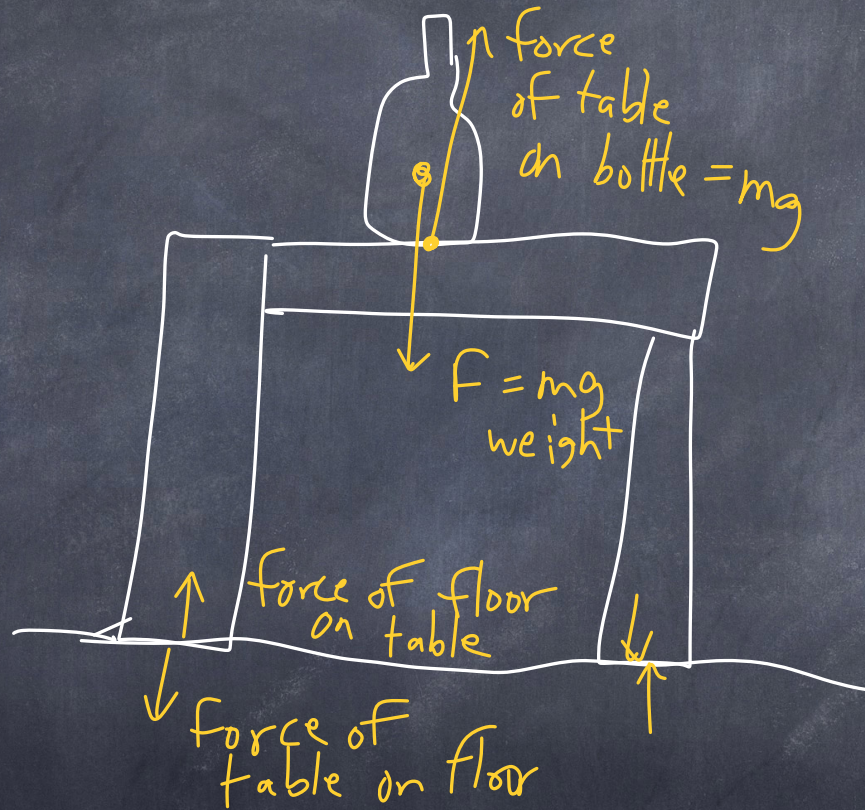


$\vec{F}_{12}$: force caused by object 1 on object 2

$\vec{F}_{21}$: force caused by object 2 on object 1

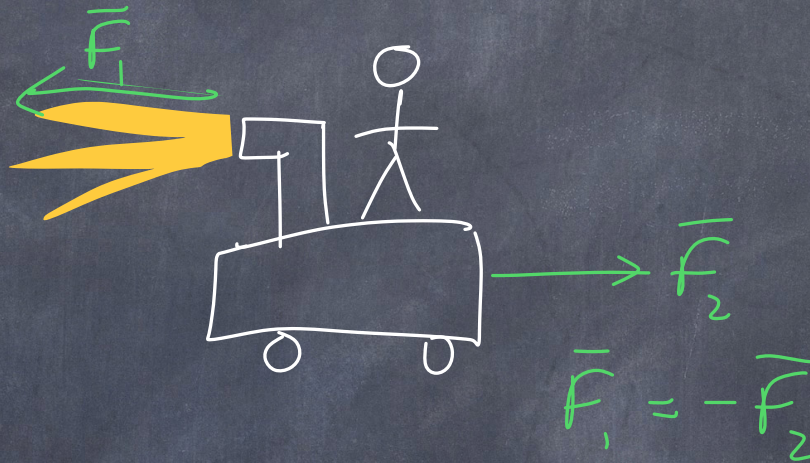
$$\vec{F}_{12} = -\vec{F}_{21}$$

Examples :



third law: "action - reaction" law

Example 2:



Example 3:



1: earth
2: person

$$\vec{F}_{21} = -\vec{F}_{12}$$

Earth feels the same force (attractive)
from the person as the person
feels from the earth.

Summary: Newton's three laws:

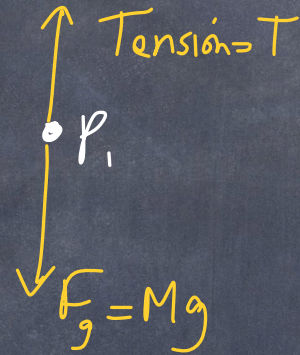
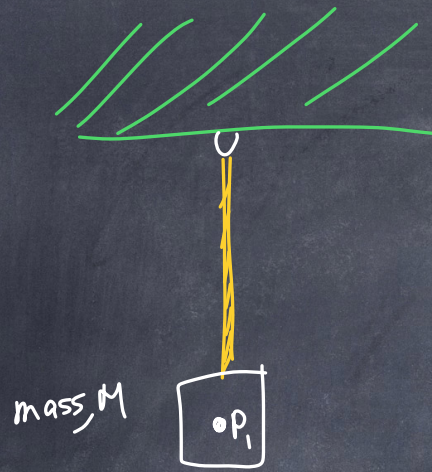
Law of inertia 1) An object will remain at rest, or continue to move in a straight line unless acted upon by a "net" force
↑
non-zero total force

$$\underline{\Sigma \vec{F} = m\vec{a}}$$

2) A net force will cause an object to accelerate according to $\Sigma \vec{F} = m\vec{a}$
↑
sum

$$\underline{\vec{F}_{12} = -\vec{F}_{21}}$$

3) When one object exerts a force on a second object, the second object simultaneously exerts a force equal in magnitude but opposite in direction on the first object.
$$\vec{F}_{12} = -\vec{F}_{21}$$



A mass M hangs from a string to the ceiling.
Draw the forces acting on P_i

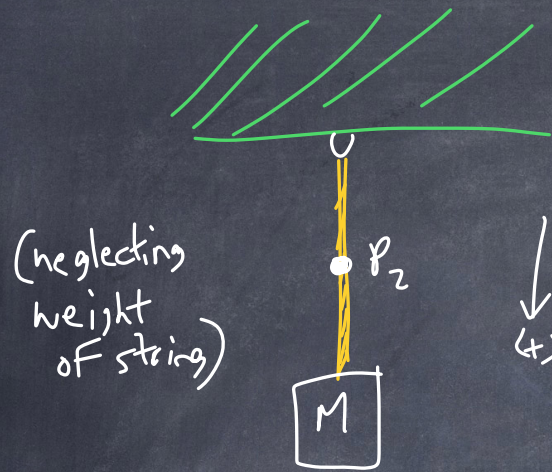
$$\Sigma F = F_g - T = 0 = ma$$

$T = F_g$ equal in magnitude

But we must specify the direction + magnitude of the forces

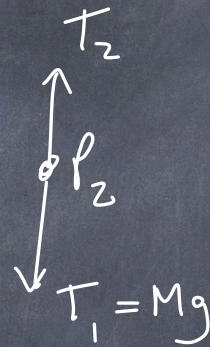
$$F_g = Mg \text{ in } (+) \text{ direction}$$

$$T = Mg \text{ in } (-) \text{ direction}$$



M : mass of block

what are the forces on P_2 ?



$$\Sigma F = T_1 - T_2 = 0$$

$$T_1 = T_2$$

$$T_1 = T_2 = Mg$$

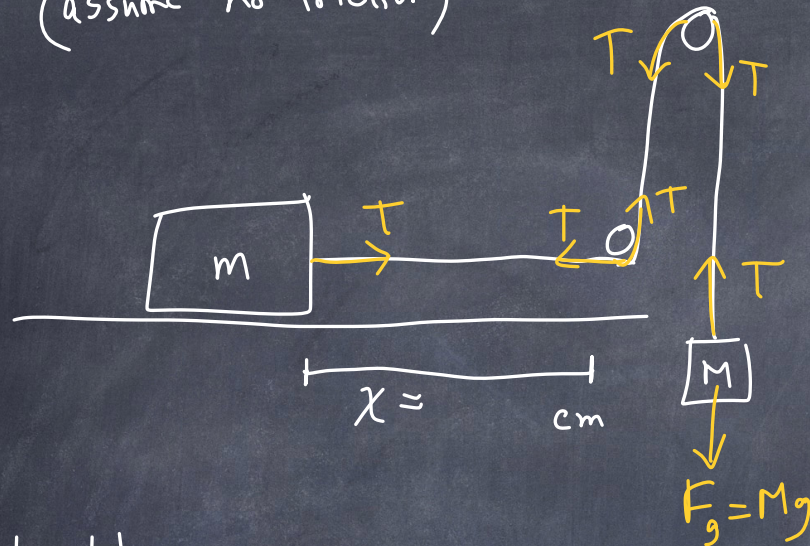
So here, $T_1 = Mg$ in (+) direction

$T_2 = Mg$ in (-) direction

∴

Tension has the same magnitude everywhere on the string.

(assume no friction)



$$m = 206g$$

$$M = 17g$$



$$\Sigma F = (\text{total mass}) a$$

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

Calculate:

$$a = \frac{Mg}{M+m}$$

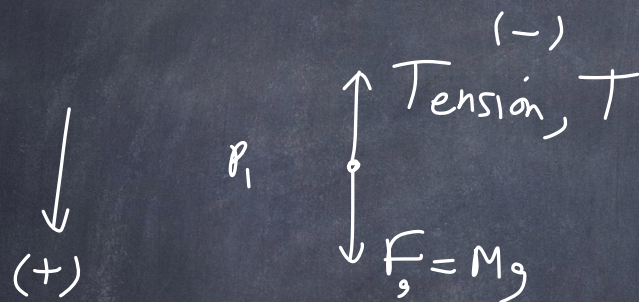
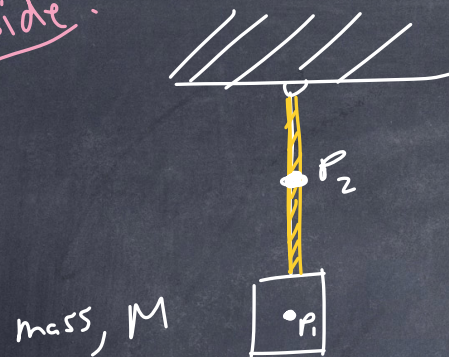
Measure:

a using

$$x = \cancel{x_0} + \cancel{v_0 t} + \frac{1}{2} a t^2 \Rightarrow a = \frac{2x}{t^2}$$

a =

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

so $\vec{F}_g = M\vec{g}$

$\vec{T} = -M\vec{g}$

Exercise:

A mass M hangs from a string to the ceiling.

Draw the forces acting at P_1 .
What about P_2 ?

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

$$F_g = Mg \text{ in } (+) \text{ direction}$$

$$T = Mg \text{ in } (-) \text{ direction}$$

↖ ↗ In both cases F_g points down
& T points up.

Aside: Sometimes people write $\frac{df(x)}{dx}$ as $f'(x)$.
These two are the same.

$$\text{Since } \frac{df(x)}{dx} = f'(x) \Rightarrow df(x) = f'(x) dx$$

And if you take the integral
of both sides:

$$\int df(x) = \int f'(x) dx$$

This becomes:

$$f(x) = \int f'(x) dx$$

which is the definition of
an integral

$$\text{Also, } \frac{d^2 f(x)}{dx^2} = f''(x)$$

