Physics 247: Lecture 6

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Until now, we have been discussing what is called "kinematics" which means we were concerned with the description of motion rather than with the "cause-effect" nature.

Example:

$$\frac{d^2x}{dt^2} = a_0 \cos(\omega t)$$

We are describing the postion of the object by x but we do not know where $a_0 \cos(\omega t)$ came from.

In this lecture, we will begin our study of Newton's laws which describe dynamics: Why is the acceleration of an object what it is?

Newtonian explanation of "why" is built on 3 postulates called Newton's laws.

These postulates ultimately can only be confirmed by experiment. When they were first postulated, they were not consequences of any more fundamental postulates.

In more advanced courses, you will learn that they are consequences a more far reaching set of assumptions. (i.e. they are no longer postulates). For every day use, treating them as

First law. An object at rest stays at rest *unless* acted on by an external force. An object in motion continues to travel with constant velocity *unless* acted on by an external force.

Inertial frame

Second law. The direction of the acceleration of an object is in the direction of the net external force acting on it. The acceleration is proportional to the net external force $\vec{F}_{net}$, in accordance with $\vec{F}_{net} = m\vec{a}$, where m is the mass of the object. The net force acting on an object, also called the resultant force, is the vector sum of all the forces acting on it: $\vec{F}_{net} = \Sigma\vec{F}$. Thus,

$$\sum\vec{F} = m\vec{a} \qquad 4\text{-}1$$

Force is a vector (adds like a vector) which leads to acceleration

Third law. Forces always occur in equal and opposite pairs. If object A exerts a force $\vec{F}_{A,B}$ on object B, an equal but opposite force $\vec{F}_{B,A}$ is exerted by object B on object A. Thus,

$$\vec{F}_{B,A} = -\vec{F}_{A,B} \qquad 4\text{-}2$$

reaction

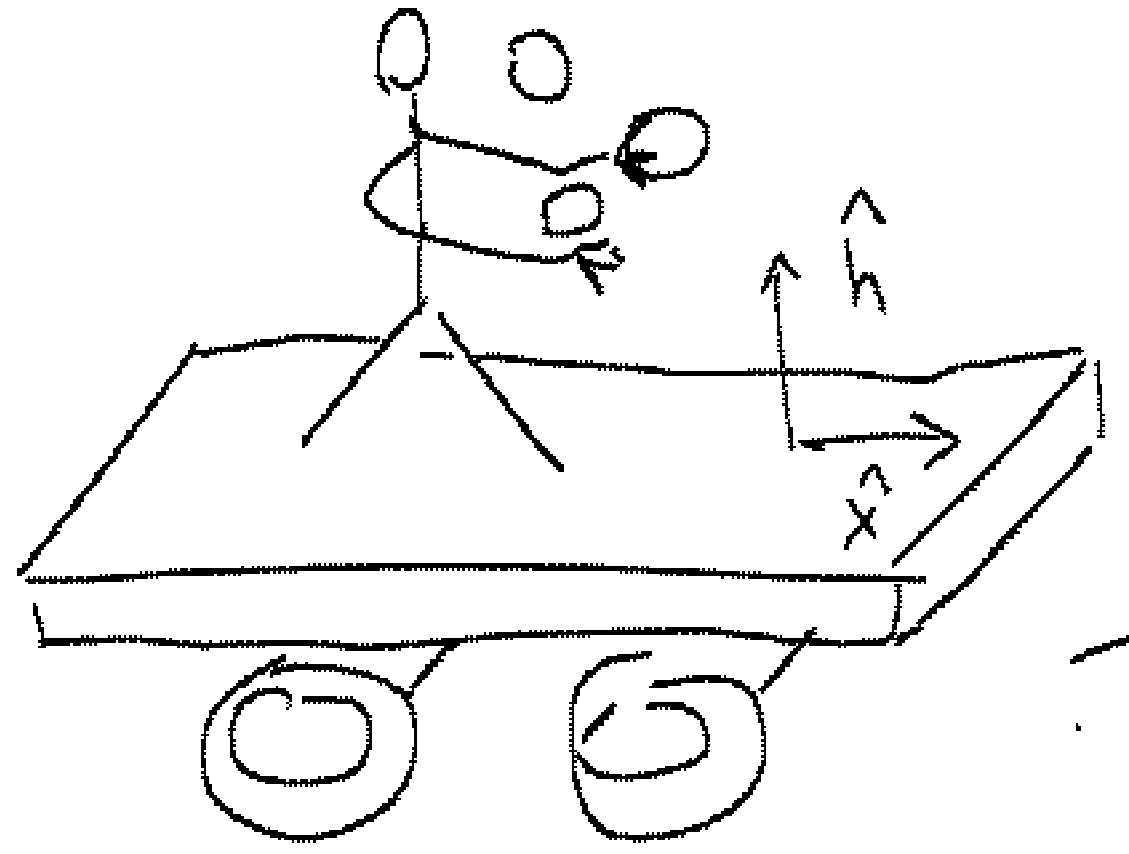
[redacted]

Reasonableness of first law:

If a clown learns to juggle on the ground, he or she can juggle in the exactly the same manner while inside of car moving at constant velocity.
That would not be true if the car is accelerating.

e.g.

Empirical reasonableness



$\vec{a}$

Consider one ball.

$$\Delta h = v_{y_0}\,\Delta t + \frac{-1}{2}\, g(\Delta t)^2$$

$$\Delta x = v_{x_0}\,\Delta t - \frac{1}{2}a\,(\Delta t)^2$$

respect to cart

non-zero if car is accelerating

As far as we know, there is nothing pushing on the ball.

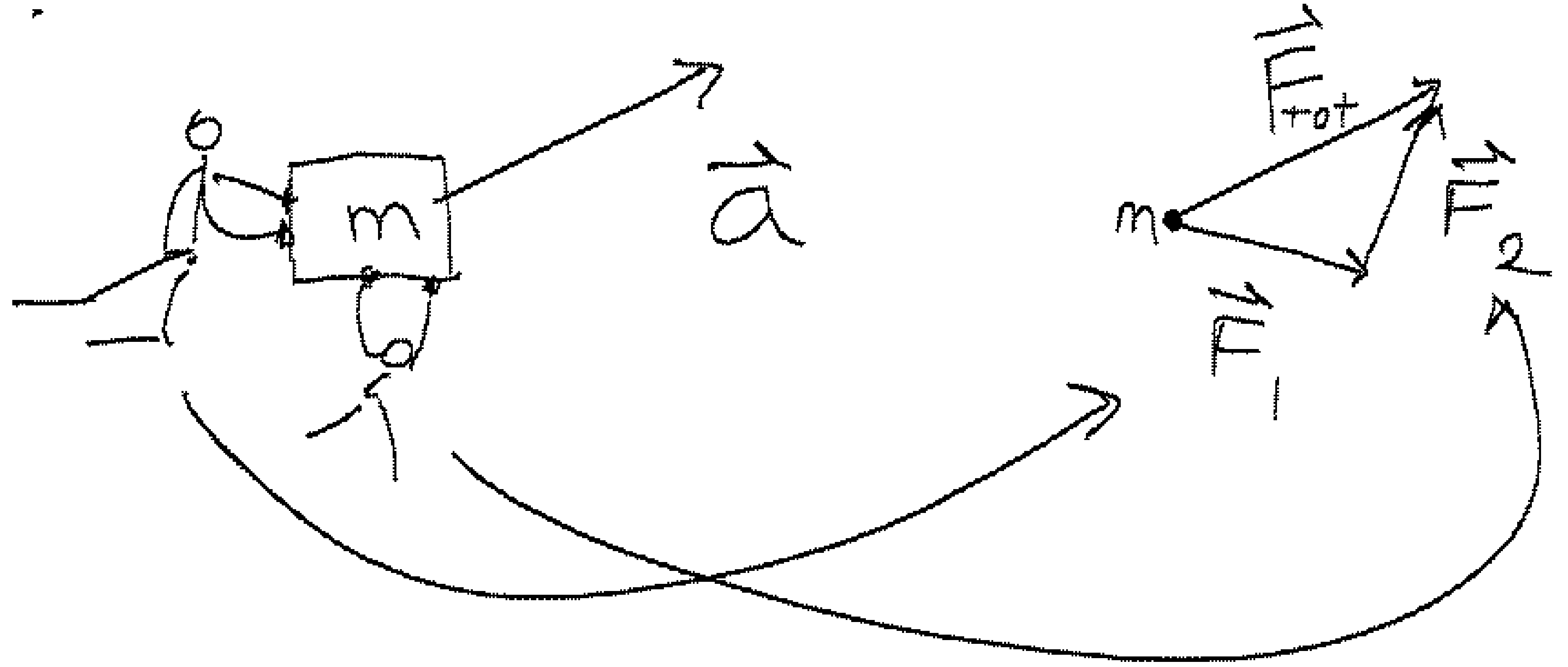
Law 1 picks out a frame to define forces = inertial frames.

Second Law:

$$\vec{F}_{tot} = \sum_i \vec{F} = m\vec{a}$$

units: $N \equiv \text{Newton} \equiv kg \frac{m}{s^2}$

e.g.



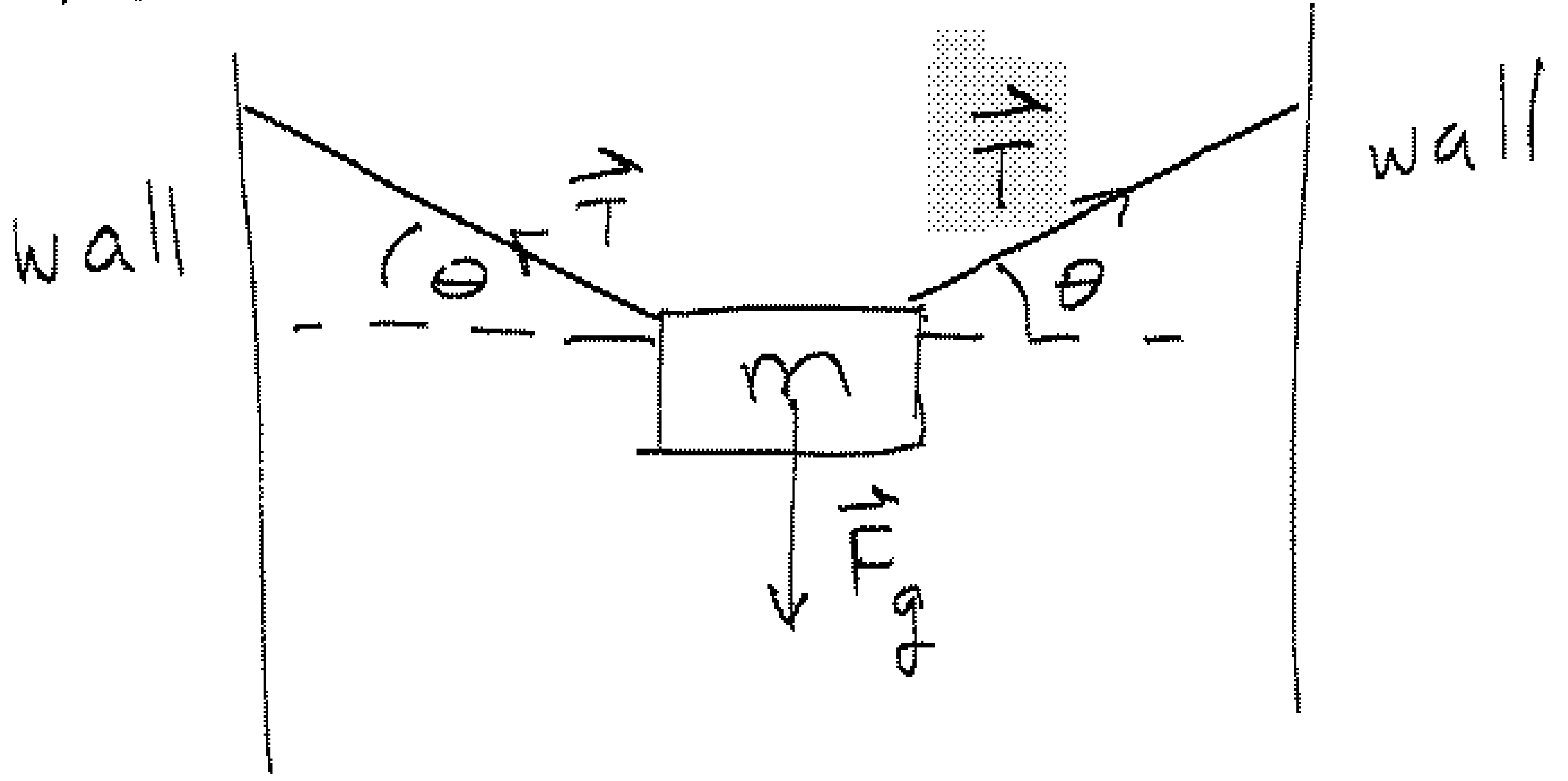
Forces add like vectors.
(a reasonable assumption)

Law 2 also defines a property of the body called mass: "m"
Same forces (or pushes) can lead to different acceleration, and this difference is a property of the body and not the external force!

Near the surface of the earth, there is a constant force field such that the force is towards the ground and pointing down.

e.g. What force must the rope provide to keep the mass from accelerating?

$\vec{g}$ = Gravitational field $\equiv$ force per unit mass

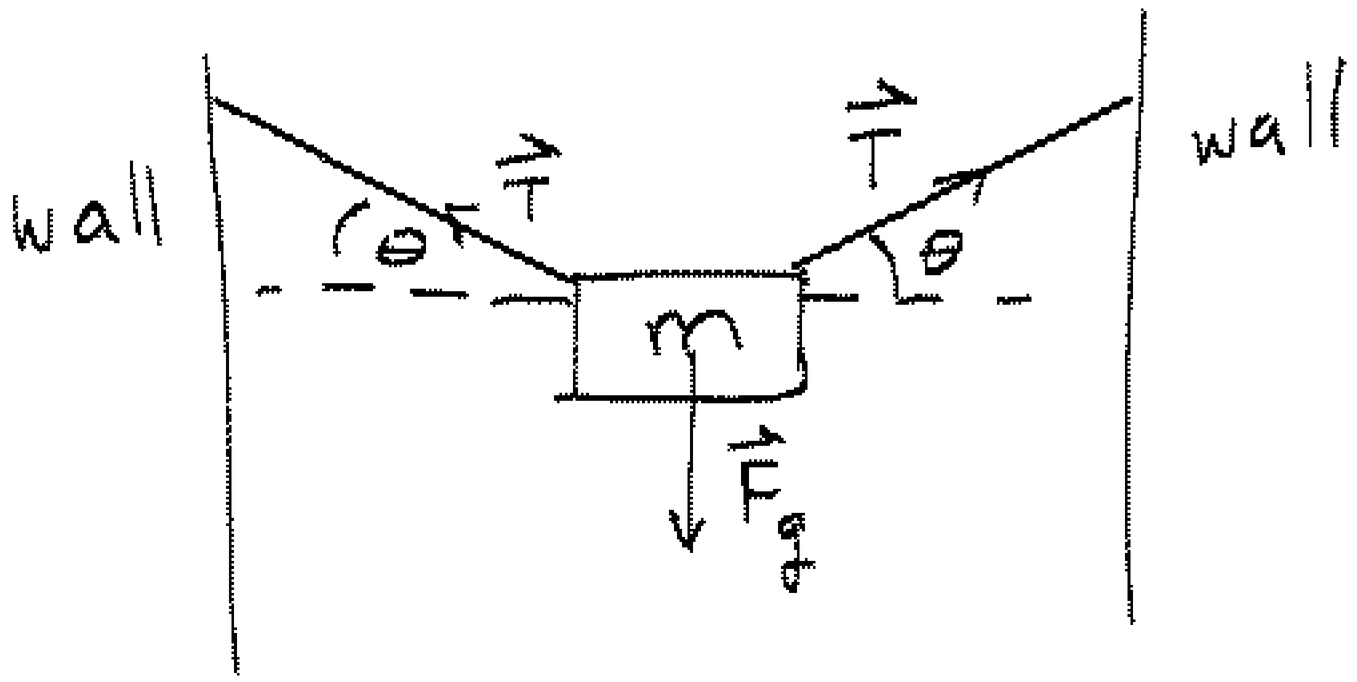


$\boxed{\vec{F}_g = m\vec{g}}$

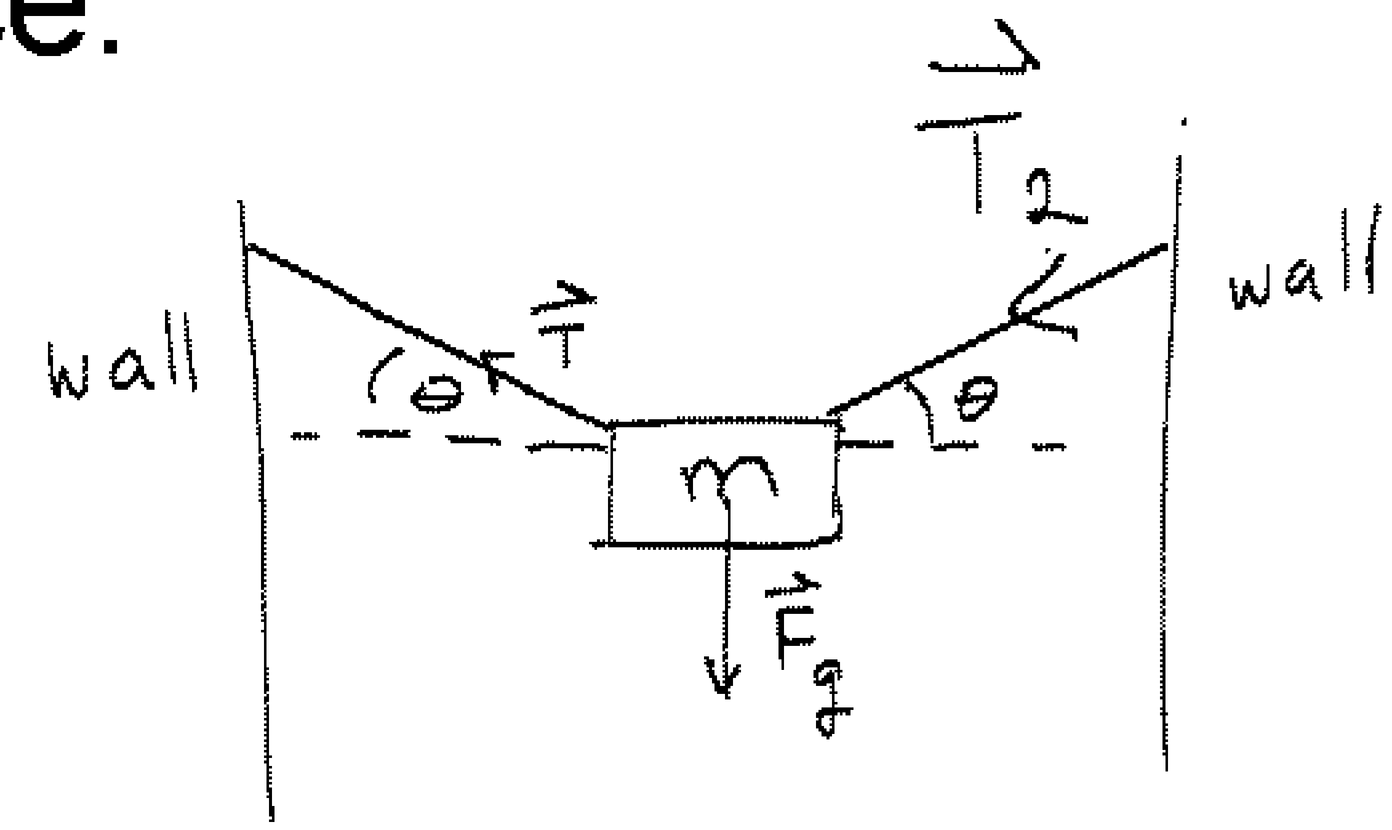
The force provided by the rope is called a tension force.

3rd Law: equal and opposite forces.

e.g.



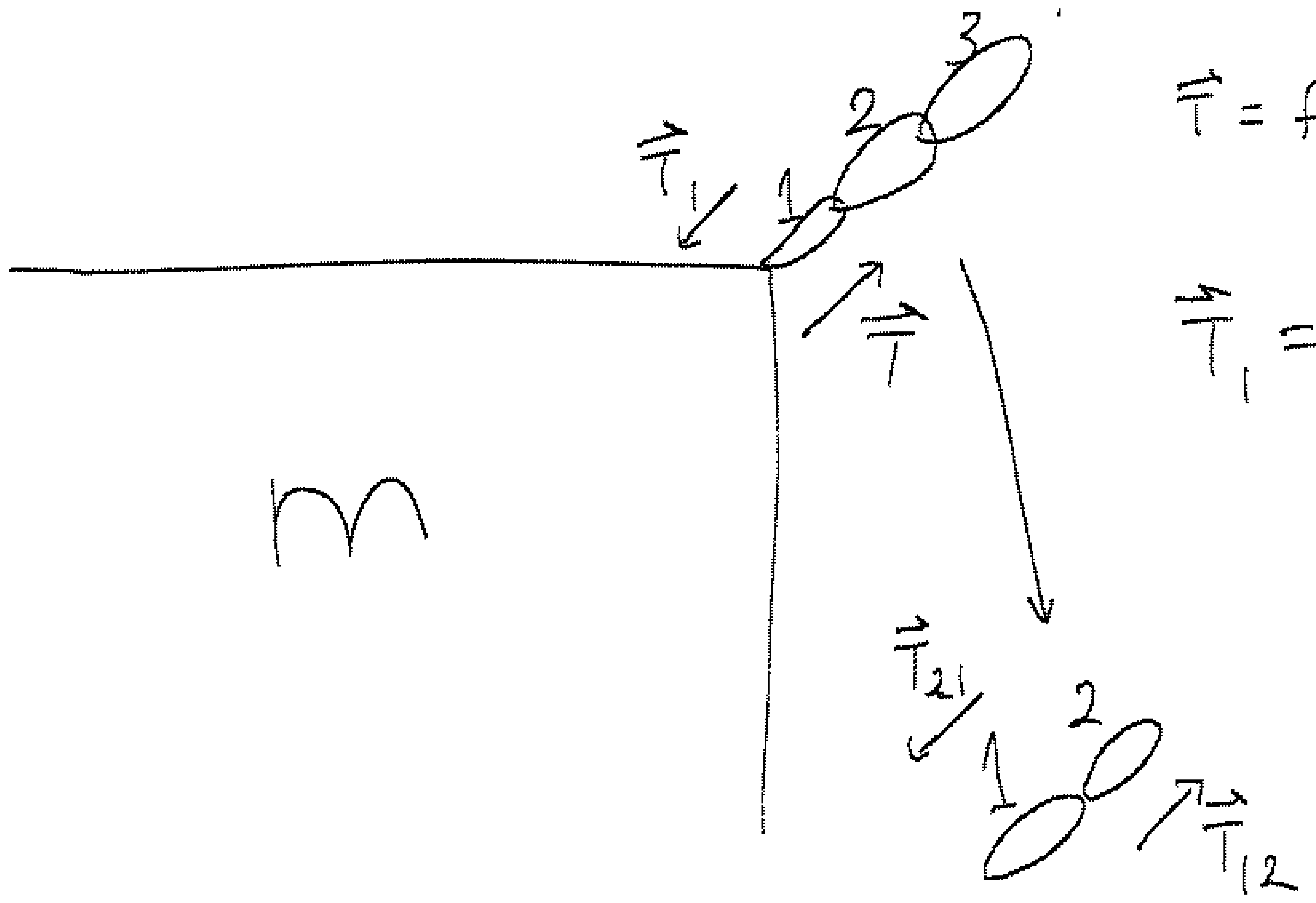
Can be viewed as the wall exerting a force on the mass through the tension of the rope.
3rd law then says that the mass is also acting on the wall with equal and opposite force.



$\vec{T}_2$ = force on wall by rope

$= -\vec{T}$

microscopically,



$\vec{T}$ = force acted on to the "m" by element 1

$\vec{T}_1$ = force acted on element 1 by "m"

$\Rightarrow$ 3rd law: $\boxed{\vec{T} = -\vec{T}_1}$

$\vec{T}_{12}$ = force acting on 1 by 2

$\vec{T}_{21}$ = force " " 2 " 1

3rd law says $\boxed{-\vec{T}_{12} = \vec{T}_{21}}$

Since element 1 is not acclerating, $\vec{T}_{12} + \vec{T} = 0$

$\therefore \boxed{\vec{T}_{21} = -\vec{T}}$

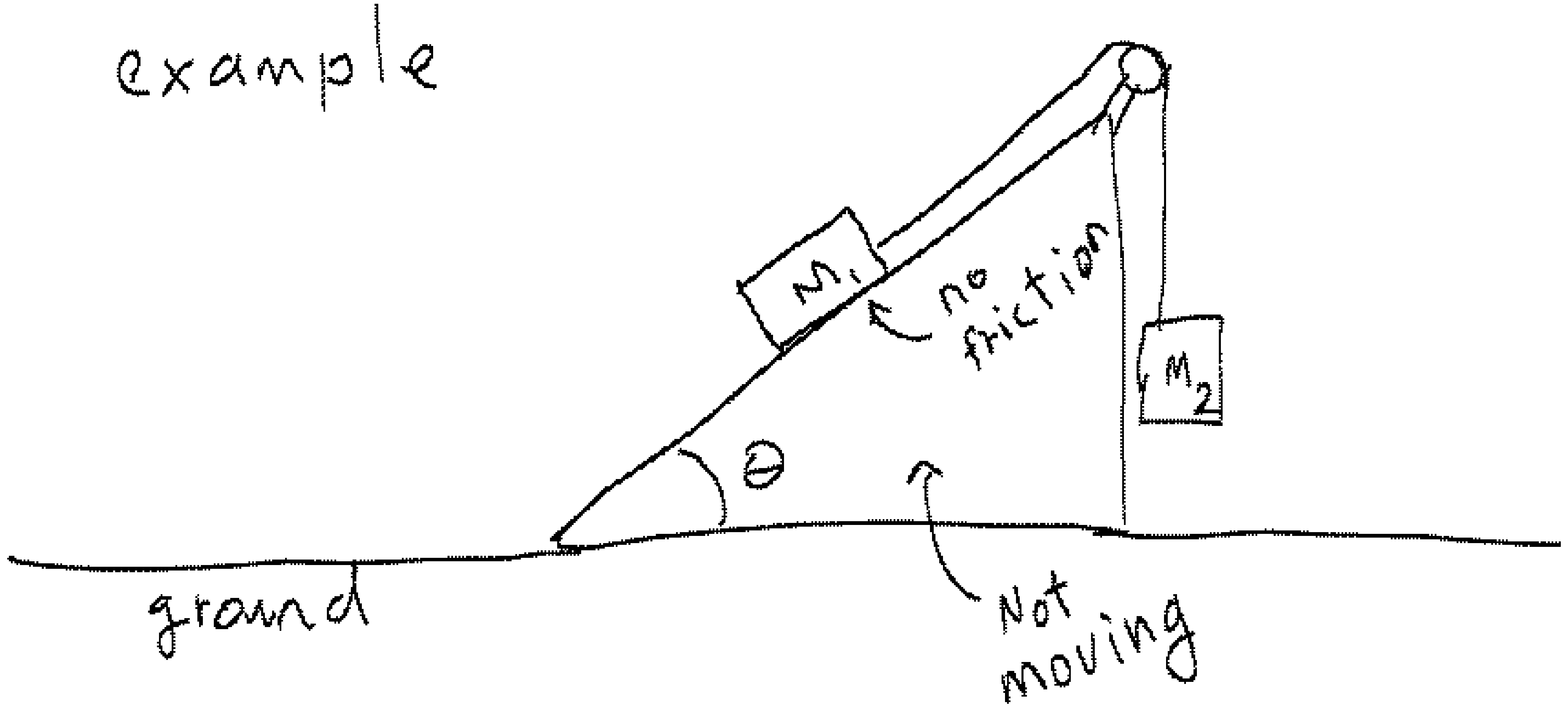
Rules for problem solving with Newton Laws:

a) Identify the variable to be solved for (position, force, etc.)
b) Label all the forces for each of the relevant bodies in the system.
c) Write Newton's second law equation for each body.
d) Use Newton's third law to write any relevant equation relating
f

ideas:

a) 1st law
b) 2nd law
c) " "
d) 3rd law

exercise: Suppose θ and M_2 are given. What must M_1 be for there to be no accel?



2 methods:

(long) a) $\{\hat{x}, \hat{y}\}$ + Normal force

(short) b) 1-step approach

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d) Use Newton's third law to write any relevant equation relating forces.