

Q1: What is force ?

1 wens)
从何处

Reference Frame

Whence the Force of $F = ma$?
I: Culture Shock

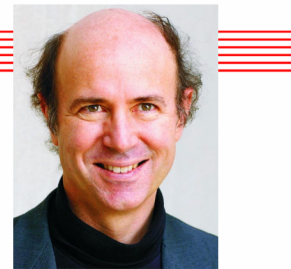
Frank Wilczek



Reference Frame

Whence the Force of $F = ma$?
II: Rationalizations

Frank Wilczek



Reference Frame

Whence the Force of $F = ma$?
III: Cultural Diversity

Frank Wilczek



physics today

Frank Wilczek is the Herman Feshbach Professor of Physics at the Massachusetts Institute of Technology in Cambridge.

Q2: is force a fundamental concept
(building block)
in modern physics ?

even absent in

quantum physics, quantum field theory

general relativity

principle of least action (even in
classical mechanics)

comment : $F = ma$ by itself does not
provide an algorithm for constructing
the mechanics of the world. The equation
is more like a common language, in which
different useful insights about the mechanics
of the world can be expressed.

why flourish? much easier to work with
extraordinary useful, one of its primary
virtues is to shield us from the
unnecessary complexity of irrelevant accuracy

our physics culture of force, properly
understood, has this profoundly modest
but practically ambitious character.

by some powerful general statements in
that language — such as the zeroth law,
the momentum conservation laws, the gravitational
force law, the necessary association of forces
with nearby sources — and then by the way
in which phenomenological observations, including
many (though not all) of the laws of
material science can be expressed in it easily

so called Newton's 1st law

惯性参考系：
空间：均匀，各向同性
时间：均匀

especially, 某时刻静止的物体将永远保持静止

Landau / Lifshitz

自由粒子永远保持静止或匀速直线运动
的状态。

赵凯华，罗蔚茵

restatement of

Galileo's principle of inertia:

If an object is left alone, is not disturbed,
it continues to move with a constant velocity
in a straight line if it was originally
moving, or it continues to stand still if
it was just standing still.

What is inertial reference frame?

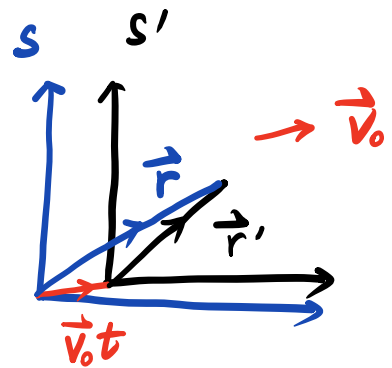
问：观察自由落体，对地静止或运动看到的有差别吗？

宿帝拉下，观察者知道自己动吗？

确定了一个惯性系后，与之相对运动为匀速运动的参考系亦为惯性系。

伽利略的时空变换关系

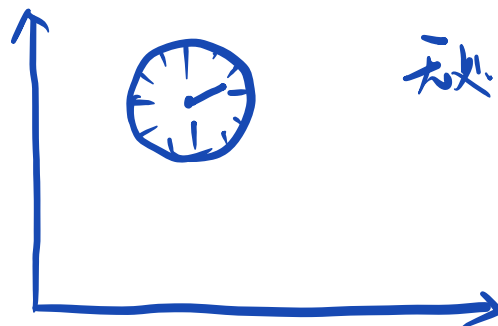
$$\begin{cases} t' = t \\ \vec{r}' = \vec{r} - \vec{v}_0 t \end{cases}$$



S' 相对于 S: \vec{v}

问 \vec{r}' , \vec{r} , \vec{v} , t , t' 谁是观测者？

$\vec{v}' = ?$, $\vec{v} = ?$



无时不存的 clock

Galileo Galilei (1564 - 1642)
 Italian astronomer
 physicist, engineer

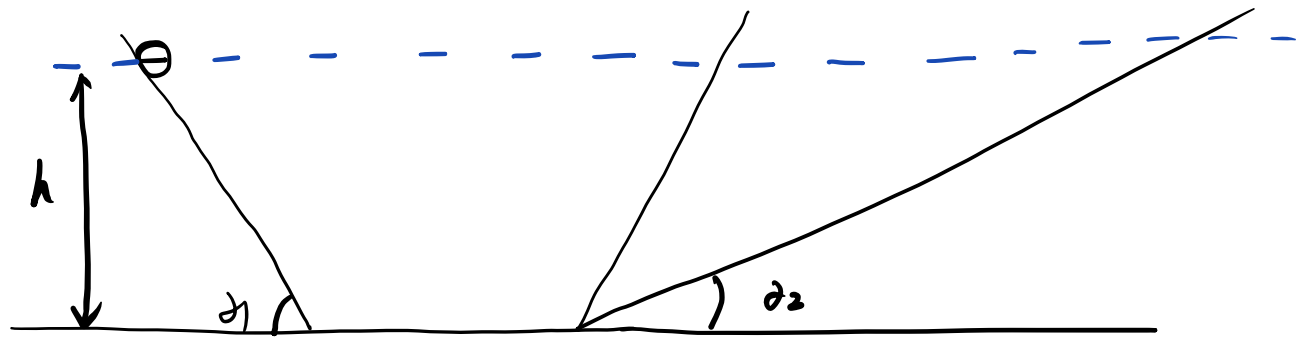
1632年
 《关于托勒密和哥白尼
 两大世界体系的对话》

爱因斯坦：伽利略的发现以及
 他所用的科学推理方法是人类思想史上
 最伟大的成就之一，而且标志着物
 理学的真正开端。
 (双斜坡理想实验)

Aristotle
 (384 - 322 BC)
 力是运动原因
 没有力物体不动
 停止是本性

Galileo vs Aristotle
 约 2000 年

今天我们知道，有摩擦力，Aristotle 的说法
 是观测的结果，如何运用科学思辨来抵
 达更深处的秘密呢？



friction
 从有到无
 (两斜坡的高度相等)

α_2 从 α_1 开始逐渐减小 $\rightarrow D$
 小球滑多远？

力是改变运动原因，而非运动原因

$$F = ma \quad (\text{2nd law})$$

Q3: what is mass?

Newton: quantity of matter

assumed it to be conserved

(zeroth law)

building blocks of matter are rearranged, but neither created nor destroyed, in physical processes;

and the mass of a body is the sum of the masses of its building blocks.

Modern view: the assumptions form an excellent approximation. ↑

nuclei, heavy atom cores, and electrons ↓

protons, neutrons ↓ (no accurate addition)

quarks, gluons (mass & energy)

go further

Q4 : How to measure mass ?

Let us ask another question first.
How does this rickety construct manage
(摇晃的)

to support stunningly precise and successful
predictions in celestial mechanics ?

———— it is bypassed
(避开)

$$F = \cancel{ma} = \frac{GMm}{r^2}$$

$$a = \frac{GM}{r^2}$$

the path is identified as a
geodesic in curved spacetime, with no mention
of mass

two-body central force :

Conservation of momentum



angular momentum

the symmetry of physical laws under translation and rotation symmetry.

天平：测的是质量吗？

$$F = ma$$



物质的量：如何比较不同材质

物质的量？

一杯水和一个铜球？

定义清晰吗？

3rd law :

every action there's an equal
and opposite reaction.



electron



electron

what is the action and reaction?