

[This course deals w/

two revolutions in physics that occurred
at the beginning of the 20th century:

quantum mechanics & special relativity.

The dates almost perfectly align w/ the beginning of the century.

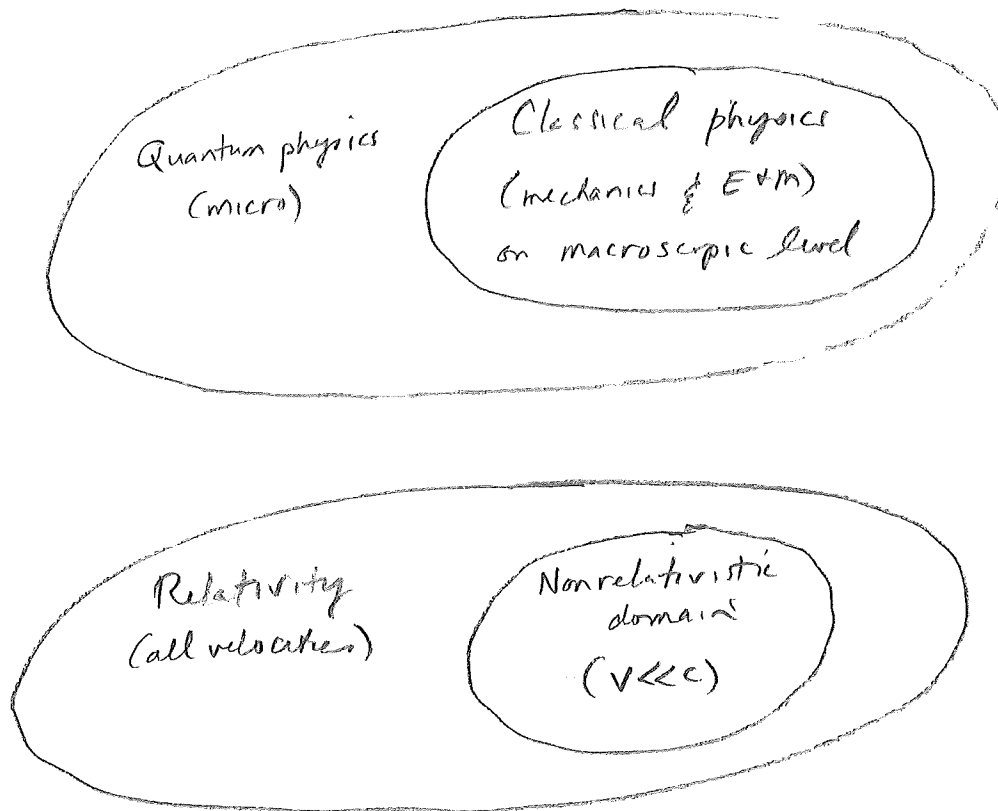
Max Planck initiated quantum mechanics in the paper
in which he introduced his famous constant in 1900.

Five years later, Albert Einstein unleashed special
relativity in his 1905 paper on electrodynamics of
moving bodies.

He also published a paper that year on the
quantization of electromagnetic waves,
which we now refer to as photons.]

"modern"
physics { 1900 Planck quantum physics
1905 Einstein special relativity

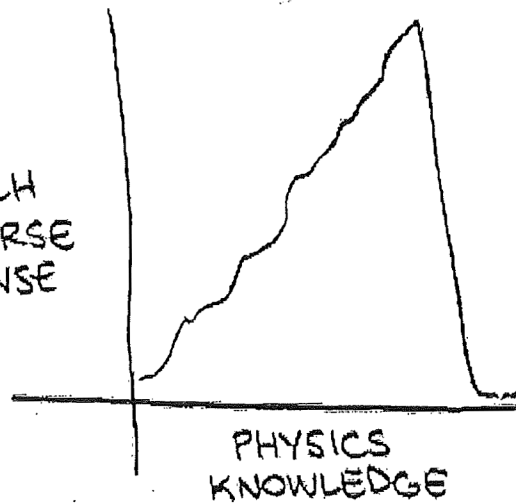
[But these were not revolutions in the traditional sense that they wiped away preceding understanding of physics. Rather they subsumed them as limiting cases.]



[Every successful theory swallows its predecessors alive.]

[These ^{new} theories have one thing in common. Both regarded as confusing and counter intuitive. In this course, we try to rebuild your intuitions.] (skip)

HOW MUCH
THE UNIVERSE
MAKES SENSE

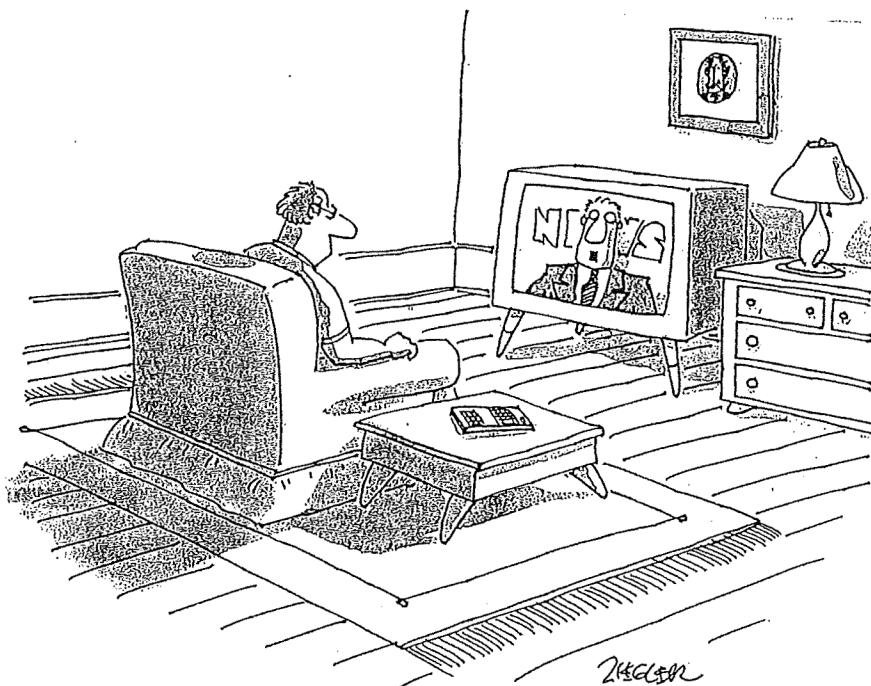


Nature and nature's laws lay hid in night;
God said, "Let Newton be!" and all was light.

—Alexander Pope

It did not last; the devil, howling "Ho!
Let Einstein be!" restored the status quo.

—unknown



*"Scientists confirmed today that everything we know about the
structure of the universe is wronged-y-wrong-wrong."*

RELATIVITY

[Although widely associated with Einstein,
the principle of relativity goes back to Galileo.
Refers to the relativity of motion.

There is no state of]

~~ABSOLUTE~~ ~~REST~~

[and no notion of]

~~ABSOLUTE~~ ~~MOTION~~

VELOCITY IS RELATIVE. (TO SOME REFERENCE FRAME)

[The velocity of an object only has meaning
when defined w.r.t. some other object,
or, if you like, w.r.t. some reference frame.
More precise definition of reference frames later.

An object may be at rest in one ref. frame (car)
but at some time in motion in another (road).

That may seem pretty trivial, even obvious.]

[What is not so obvious is that
from point of view of laws of physics,
all (inertial) reference frames are equivalent.]

GALILEO'S PRINCIPLE OF RELATIVITY (1632)

LAWS OF PHYSICS ARE THE SAME IN
ALL (INERTIAL) REFERENCE FRAMES.

(EQUATIONS OF PHYSICS TAKE THE SAME FORM.)

[i.e. Things behave same way in an environment
moving w/ constant velocity as in a stationary one.]

[not self evident!]

based on experience

see Galileo's dialogue

‡Galileo Galilei, *Dialogue Concerning the Two Chief World Systems—Ptolemaic and Copernican*, first published February 1632; the translation quoted here is by Stillman Drake (University of California Press, Berkeley, 1962), pages 186ff. Galileo's writings, along with those of Dante, by reason of their strength and aptness, are treasures of human thought, studied today in Italy by secondary school students as part of a great literary heritage.

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SALVATIUS: Shut yourself up with some friend in the main cabin below decks on some large ship, and have with you there some flies, butterflies, and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle that empties drop by drop into a wide vessel beneath it. With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distances being equal; jumping with your feet together, you pass equal spaces in every direction. When you have observed all these things carefully (though there is no doubt that when the ship is standing still everything must happen in this way), have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still. In jumping, you will pass on the floor the same spaces as before, nor will you make larger jumps toward the stern than toward the prow even though the ship is moving quite rapidly, despite the fact that during the time that you are in the air the floor under you will be going in a direction opposite to your jump. In throwing something to your companion, you will need no more force to get it to him whether he is in the direction of the bow or the stern, with yourself situated opposite. The droplets will fall as before into the vessel beneath without dropping toward the stern, although while the drops are in the air the ship runs many spans. The fish in their water will swim toward the front of their bowl with no more effort than toward the back, and will go with equal ease to bait placed anywhere around the edges of the bowl. Finally the butterflies and flies will continue their flights indifferently toward every side, nor will it ever happen that they are concentrated toward the stern, as if tired out from keeping up with the course of the ship, from which they will have been separated during long intervals by keeping themselves in the air. . . .

SAGREDUS: Although it did not occur to me to put these observations to the test when I was voyaging, I am sure that they would take place in the way you describe. In confirmation of this I remember having often found myself in my cabin wondering whether the ship was moving or standing still; and sometimes at a whim I have supposed it going one way when its motion was the opposite. . . .

[Since things always come out the same in all REF's,
cannot conduct any experiment to determine
whether you are moving or not.]

NO EXPERIMENT CAN DISTINGUISH AMONG REF. FRAMES,
or NO EXPERIMENT CAN DETECT ABSOLUTE MOTION

→ [we'll use this later in
discussing Einstein's theory]

[Historical context:]

Galileo had small disputes w/ religious authorities

He claimed earth is orbit around sun (30 km/s)

They argued that earth is at rest, because
seems at rest

He argued that things behave the same
whether at rest or in motion

His "stg" was the earth]

[Why do we associate relativity w/ Einstein?]

[19th century: light = electromagnetic waves]

MAXWELL'S EQUATIONS PREDICT
LIGHT WAVES TRAVEL AT (constant) SPEED c .

ABSOLUTE SPEED OF LIGHT APPARENTLY VIOLATES
PRINCIPLE OF RELATIVITY.

[How can Maxwell's eqns be true in all frames?]

In a frame moving at speed c , light would appear
stationary.

Maxwell's eqns do not allow stationary wave,
so cannot be valid in that frame]

19th CENTURY PHYSICISTS POSTULATED:

LUMINIFEROUS ETHER, MEDIUM FOR LIGHT WAVES.

CLAIMED MAXWELL EQNS ONLY VALID IN REST FRAME OF ETHER

[Expt failed to detect any ether. Michelson-Morley]

EINSTEIN CLAIMED ETHER DIDN'T EXIST AND THAT
MAXWELL'S EQNS HOLD IN ALL FRAMES

[How possible? Required radical reformulation of space & time]