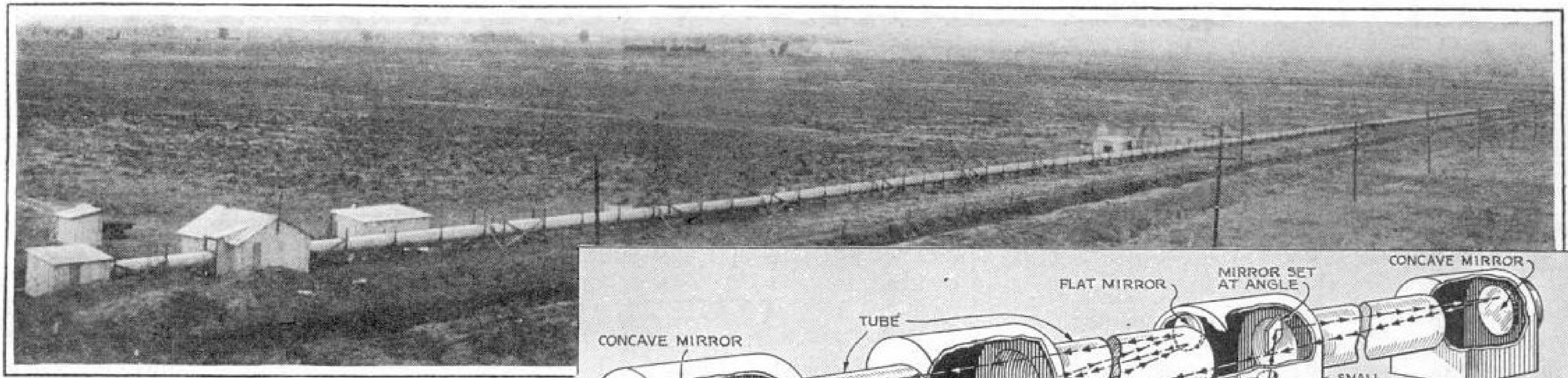
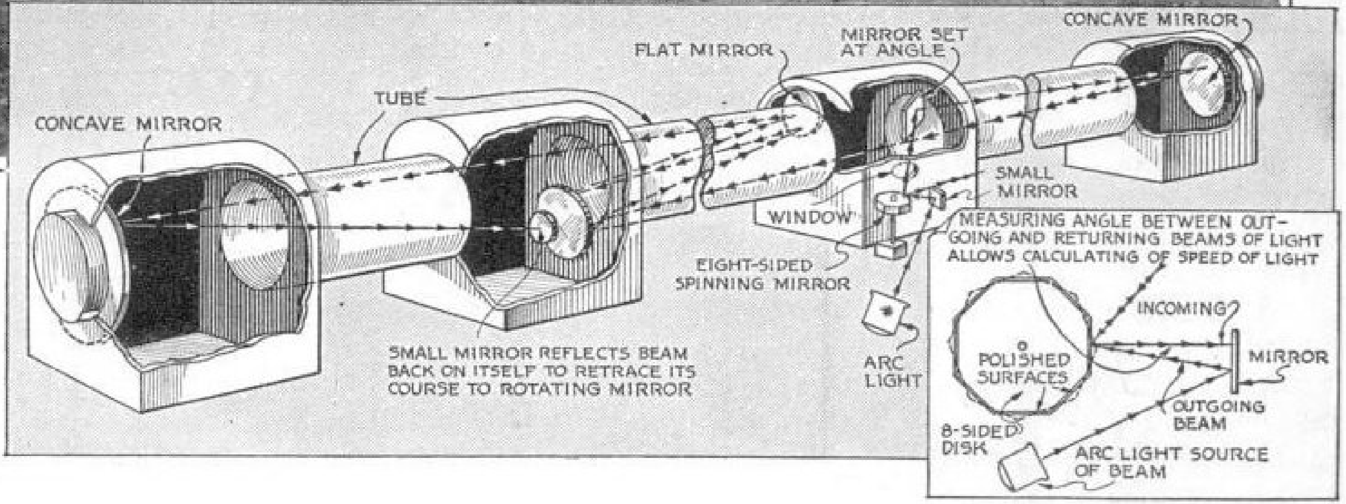
How Fast Do Electromagnetic Waves Travel?

- It took awhile for scientists to understand that electricity and magnetism were two sides of the same coin
  - You can’t have one without the other
- Lots of early scientists thought there had to be a medium to carry electromagnetic waves
  - Would you believe “luminiferous aether?”
  - Big conceptual leap: light and electromagnetic waves are the same thing
- Three key points proven early on:
  - All electromagnetic waves travel at the same rate regardless of frequency (wasn’t obvious early on)
  - No “medium” is needed (this was hard for lots of people to accept!)
  - The speed of light is not infinite
- Many early attempts to measure the speed of light
  - Even the ancient Greeks got in on the action, though they went way off in the wrong direction
  - Albert Einstein showed that the speed of light, c, is a fundamental, universal constant
  - He also made some early breakthroughs defining light, and hence EM waves, as photons

An Experiment in the 1930s



A view of the mile-long vacuum tube, three feet in diameter, lying in a California valley. This is the main feature of the apparatus used by Dr. Michelson.



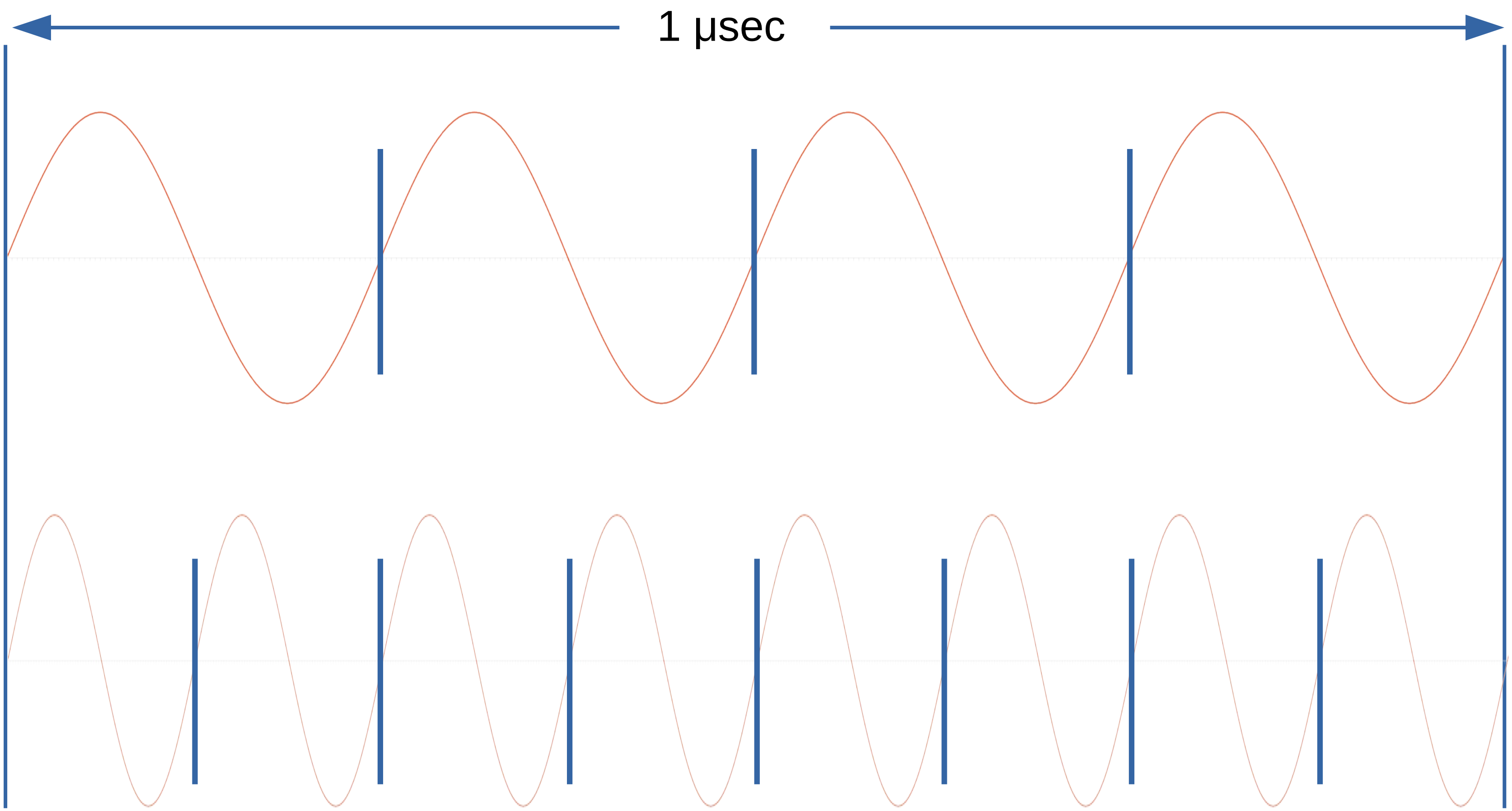
At right, the drawing shows the giant tube which Michelson is using, with the arrangement of mirrors which reflect the light ray up and down the tube until it has traveled ten miles. Inset shows how speed of light is calculated from the known angle.

So How Fast Does Light Travel?

- C, the speed of light, is the same in all inertial reference systems (Einstein)
- We now define the meter in terms of the speed of light:
  - Light travels in a vacuum at 299,792,458 meters/second (by definition)
  - Or, one meter is how far light travels in 1/299,792,458 sec
- Usually we say light travels 300 x 10^6 m/s
  - Or, more usefully, light travels 300 meters in one microsecond
  - Note that light slows down when not in a vacuum. For example, in air, light travels at 0.9997 of c (usually ignored)
  - Speed of radio waves in copper wire is about 0.95 c (the 0.95 is called the velocity factor)

Introducing Frequency and Wavelength

- Pretend for a moment that an electromagnetic wave is a vibration in the luminiferous aether
- Frequency is the number of times per second that the wave goes from most positive, to most negative, then back to most positive
  - Actually we generally measure from positive-going zero crossing to the next positive-going zero crossing
  - Measured in hertz (Hz)
  - If, instead of one sec, we use 1 μsec, then frequency is in Megahertz (MHz)
- Wavelength is the distance that a single cycle of a wave travels, measured in meters


1 µsec

Wavelength is Inverse of Frequency

$$\text{Frequency (MHz)} = \frac{300}{\text{Wavelength (meters)}}$$

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Fundamental Antenna is the Dipole

- If someone says “dipole” without otherwise qualifying it, it usually means half-wavelength
  - It is the fundamental electric-field resonant antenna
  - How you feed it doesn’t matter—a dipole is a dipole!
- To make a dipole, we can compute how long it needs to be to be ½ wavelength (½ λ)
- Don’t forget that velocity factor in wire is ~0.95

$$\text{Wavelength (meters)} = \frac{300}{\text{Frequency (MHz)}}$$

There are 3.281 ft/meter, so:

$$\text{Wavelength (feet)} = \frac{300 \times 3.281}{\text{Frequency (MHz)}} = \frac{984.3}{\text{Frequency (MHz)}}$$

But we want a half wave, so multiply both sides by 1/2

$$\text{Halfwave (feet)} = \frac{492}{\text{Frequency (MHz)}}$$

Now apply velocity factor of 0.95

$$\text{Halfwave (feet)} = \frac{492 \times 0.95}{\text{Frequency (MHz)}} = \frac{468}{\text{Frequency (MHz)}}$$

https://youtu.be/VOkOj5TkzAw