Measuring the Speed of Light

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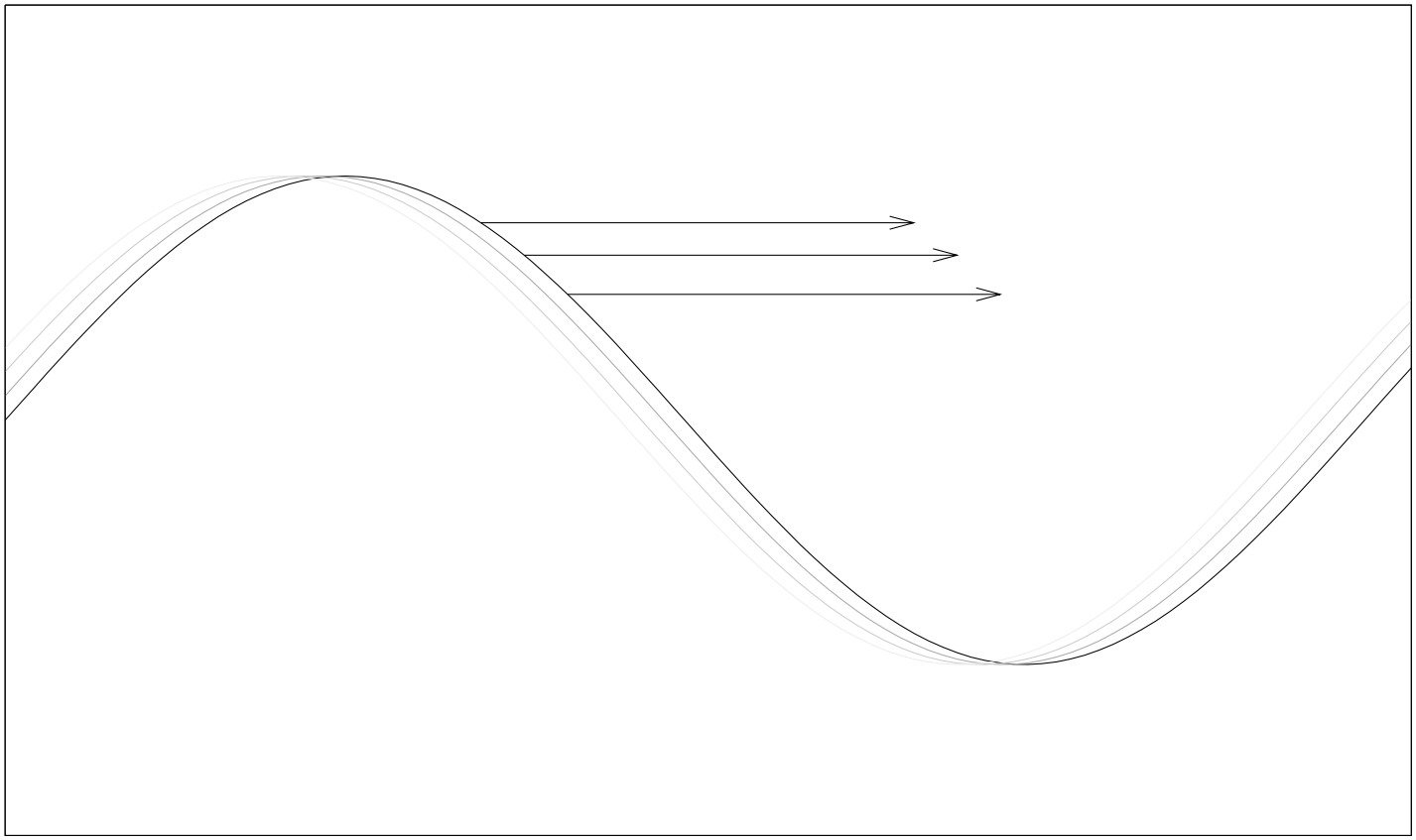
How?

- Light is very fast, so need a trick.
- We know light is a *electromagnetic wave*.

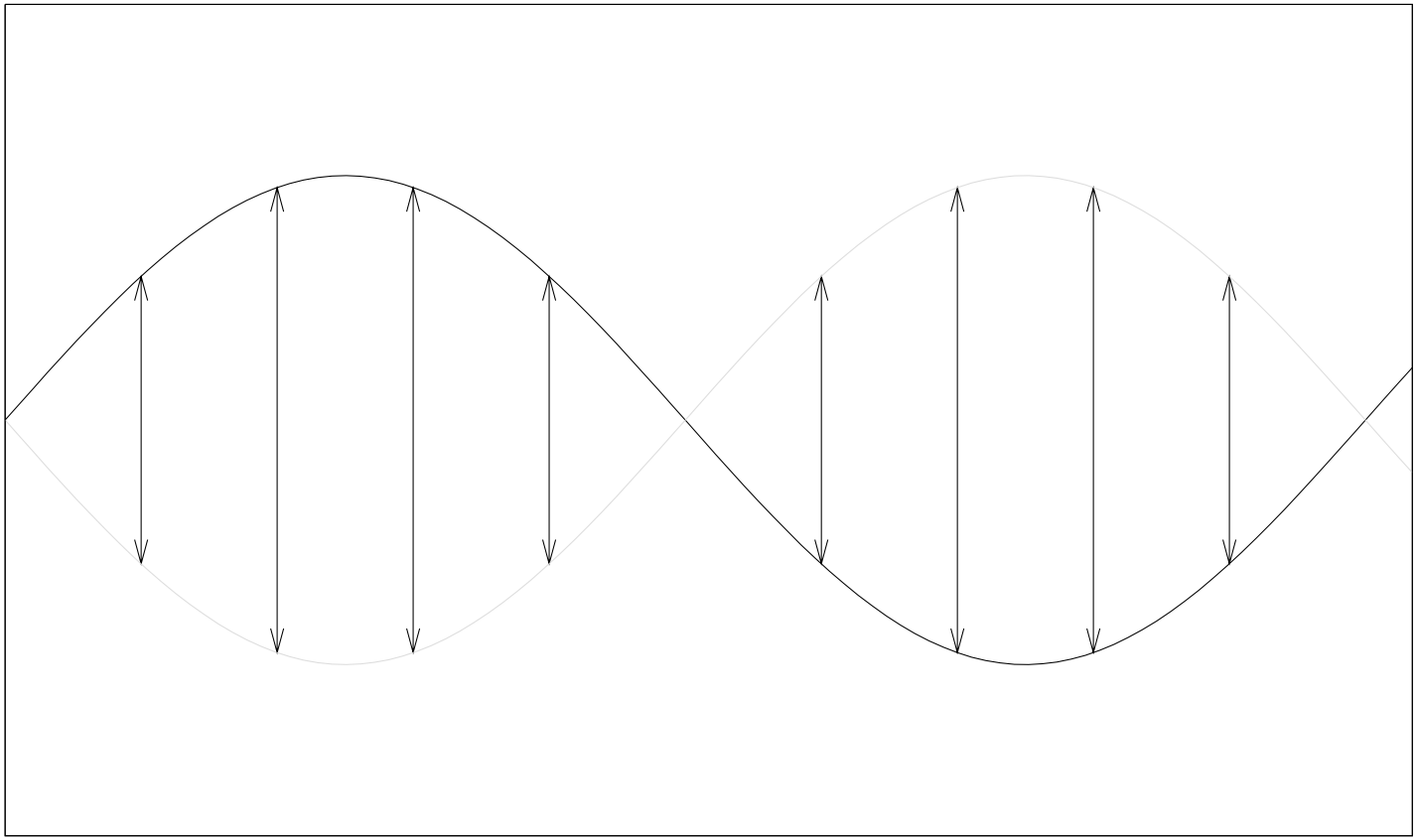
What's a wave?

Special Wave



A bit like a wave on the sea.

Standing Wave



A bit like the string of a guitar.

The Trick

Both types of wave obey the wave equation:

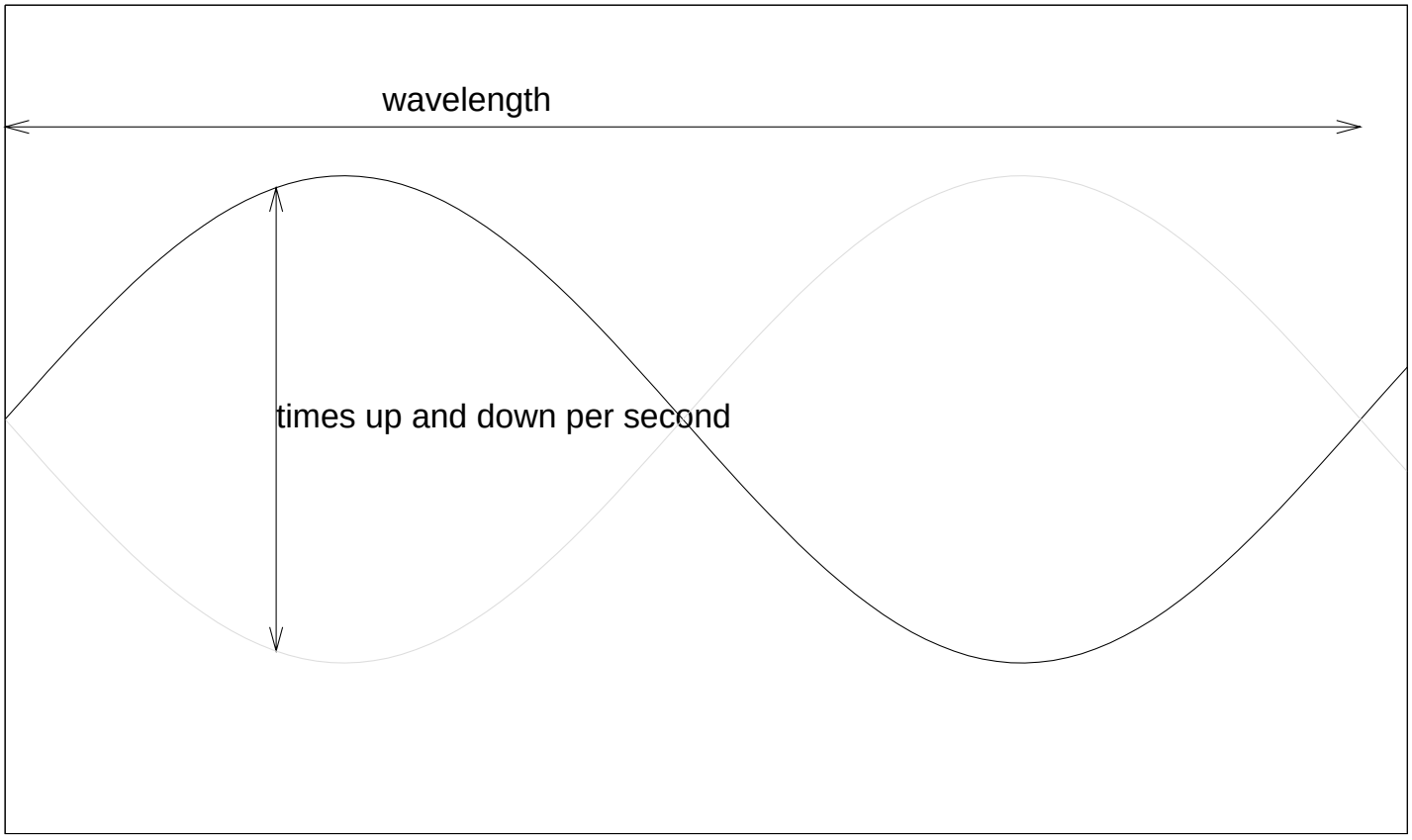
$$\frac{1}{c^2}\frac{\partial^2 E}{\partial t^2} = \nabla^2 E,$$

and wave equation tells us:

$$c = \lambda f$$

And c is the speed of the moving wave.

So, Measure the Standing Wave!



Where to find electromagnetic standing wave?
Microwave ovens use them!

EM Wave Detector

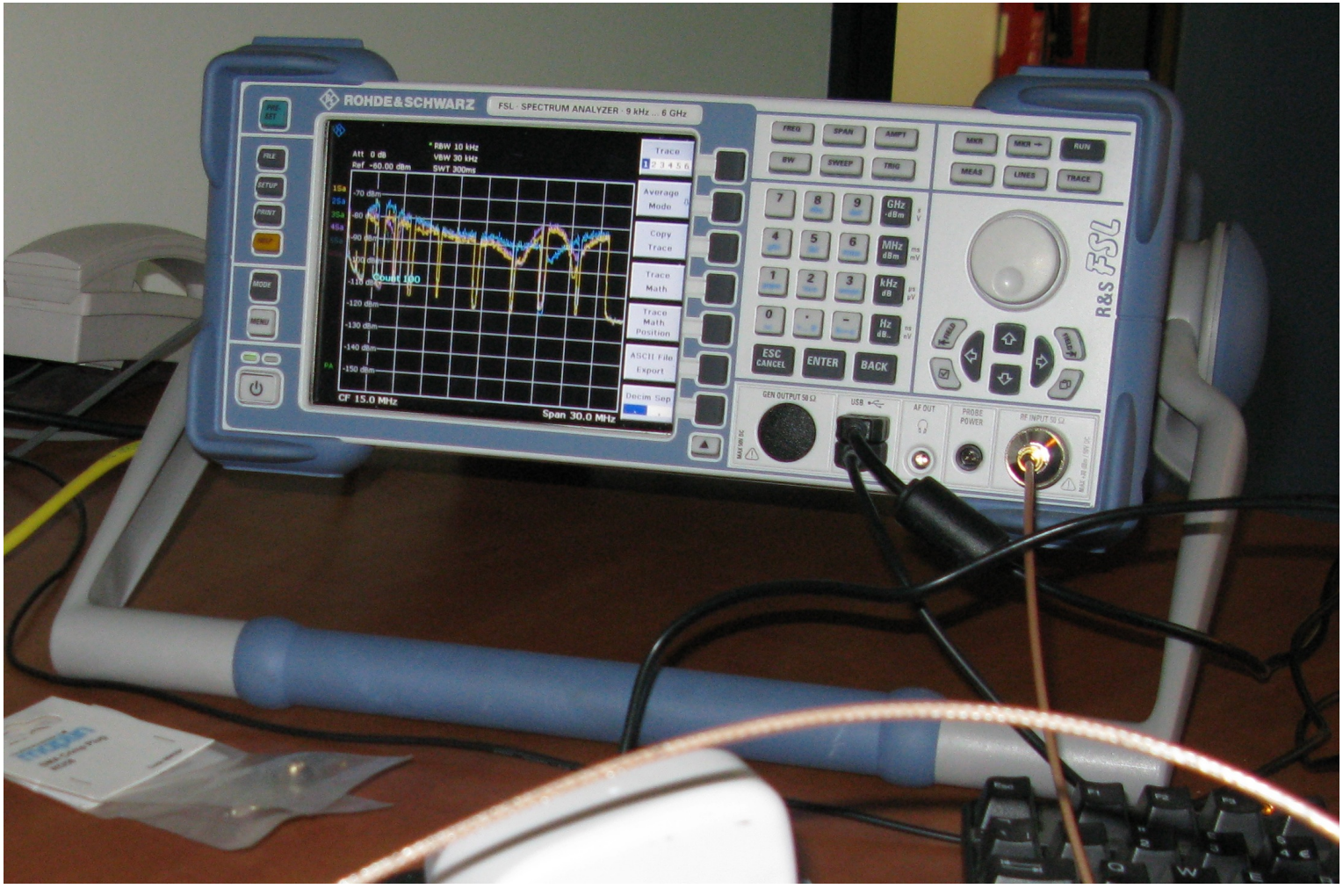
- Wave does more work where peaks are.
- Make use of the Easy Single. . .
- . . . and some card to avoid turntable.

How do we measure frequency?

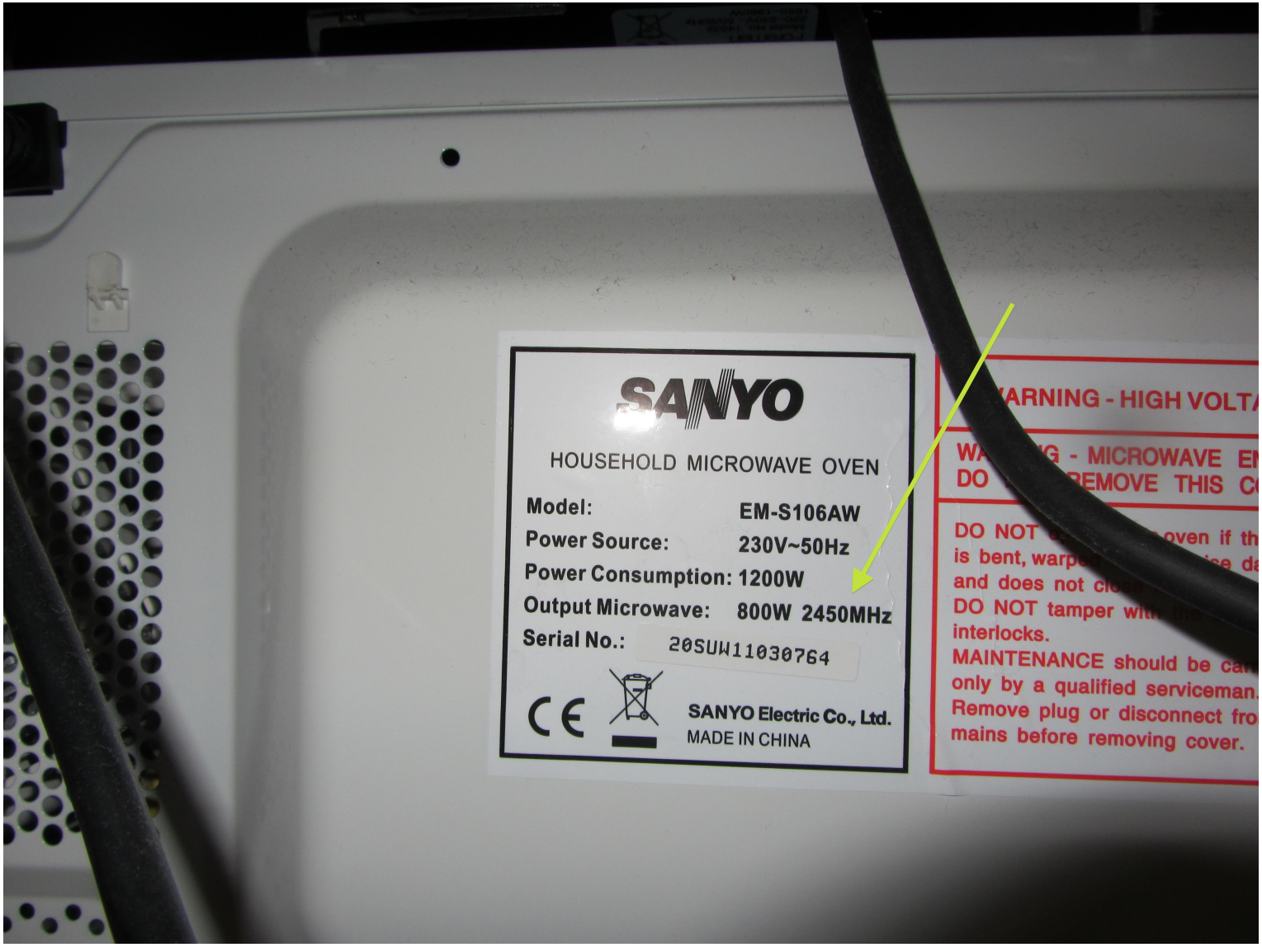
- Light,
- Electromagnetic waves,
- Microwaves,
- X-rays,
- Radio waves,
- ...

All the same thing. Could use a radio?

Spectrum Analyser



But, there's a cheaper way . . .



Ding!

And the answer is!

Wavelength (cm)	Speed (millions of metres per sec)
5	122
6	147
7	171
8	196
9	220
10	245
11	269
12	294
13	318
14	343
15	367
16	392
17	416
18	441
19	465

But...

- We used a trick: light is an EM wave.
- How do we know?

Well, Maxwell gave us his equations in 1860s.

$$\rightarrow \quad \begin{aligned} \nabla \cdot E &= 0 \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times B &= \mu_0 \epsilon_0 \frac{\partial E}{\partial t} \end{aligned}$$

Maxwell's Equations

He rearranged them and found...

$$\frac{1}{\mu_0 \epsilon_0} \frac{\partial^2 E}{\partial t^2} = \nabla^2 E,$$

"That's a wave equation, I wonder what speed it goes at?"

He knew μ_0 and ϵ_0, and figured out c...

Holy Moly!

It was 300 million metres per second!

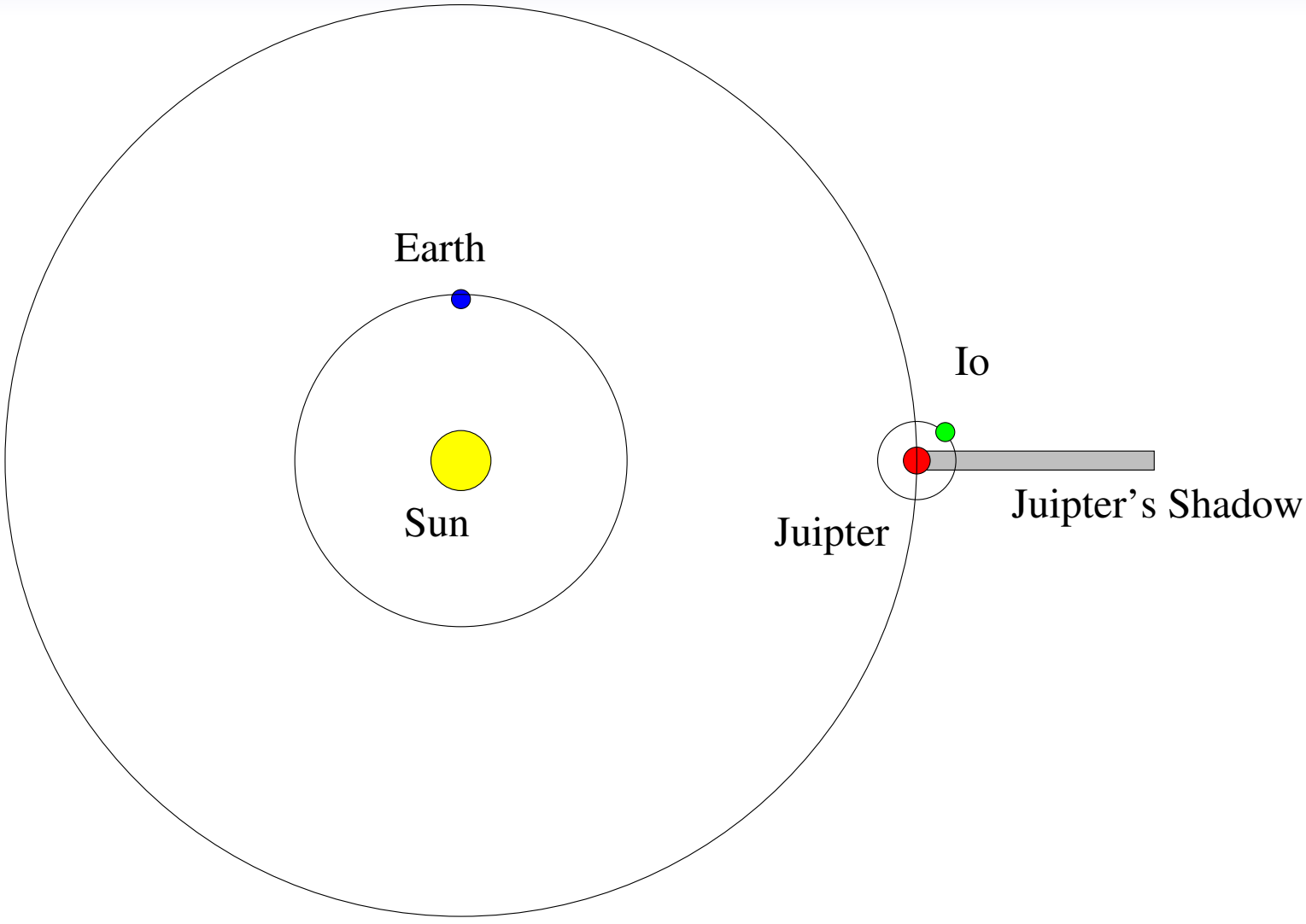
- So, light was probably an EM wave,
- maybe could make EM waves?

But, how did they know speed of light in 1860s?

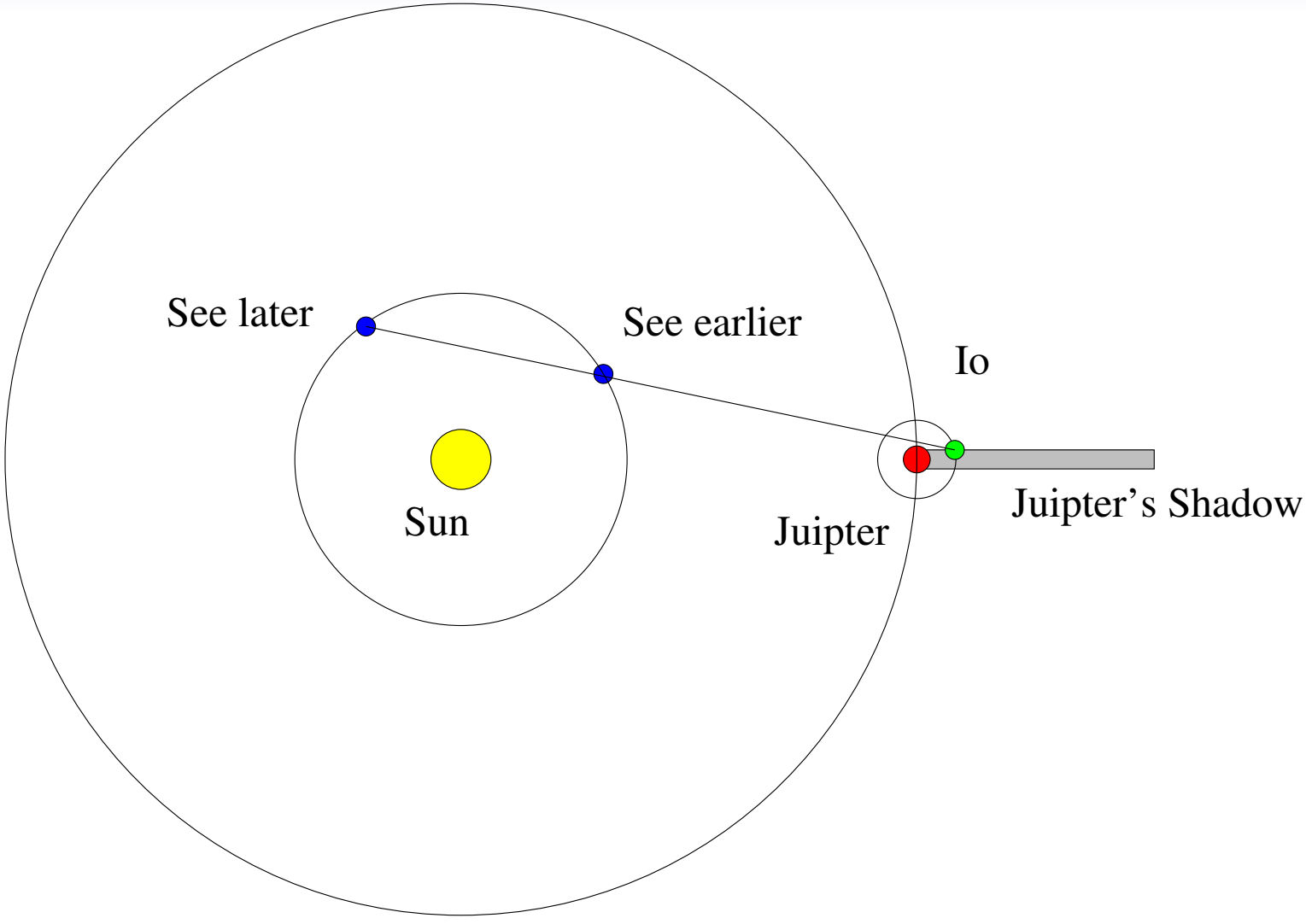
Clocks for Navigation

Back to the 1660s.

- Good clocks useful for navigation.
- Jupiter moon Io makes a reasonable clock.



You can see it going in and out of shadow, but it's a bit irregular.



Rømer estimated 22 min to cross orbit, modern value 16 mins.

In summary

- We measured the speed of light.
- Using cheese and a microwave.
- If you don't believe me, go check out Jupiter!