

Until the discovery of fusion, this is what astronomers believed was the power source for the Sun:

Gravitational Energy : Dropping Mass

$$E \simeq \frac{G M^2}{R}$$

E = energy released from dropping

G = gravitational constant

M = mass of spherical object

R = radius of spherical object

$$M_{\odot} = 2.0 \times 10^{30} \text{ kg}$$

$$R_{\odot} = 7.0 \times 10^8 \text{ m}$$

$$G = 6.67 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$$

How much gravitational energy is released in assembling the Sun? What is the efficiency of this?

$$E \simeq \frac{G M^2}{R} = \frac{\left(6.67 \times 10^{-11} \frac{\text{m}^3}{\text{kg s}^2}\right) (2.0 \times 10^{30} \text{ kg})^2}{7.0 \times 10^8 \text{ m}}$$
$$= 4 \times 10^{41} \text{ J}$$

$$eff = \frac{3.8 \times 10^{41} \text{ J}}{(2.0 \times 10^{30} \text{ kg}) (3.00 \times 10^8 \text{ m/s})^2}$$
$$= 2 \times 10^{-6}$$

Still not good enough; we need at least 1000× more energy

To have been shining at its current luminosity for a few billion years, the sun needs an energy generation processes that has an efficiency of about 10^{-3} (or even a bit better).

Gravitational contraction of something the size and mass of the Sun has an efficiency of about 10^{-6} .

If the Sun were generating its power through gravitational contraction, how old could it be?

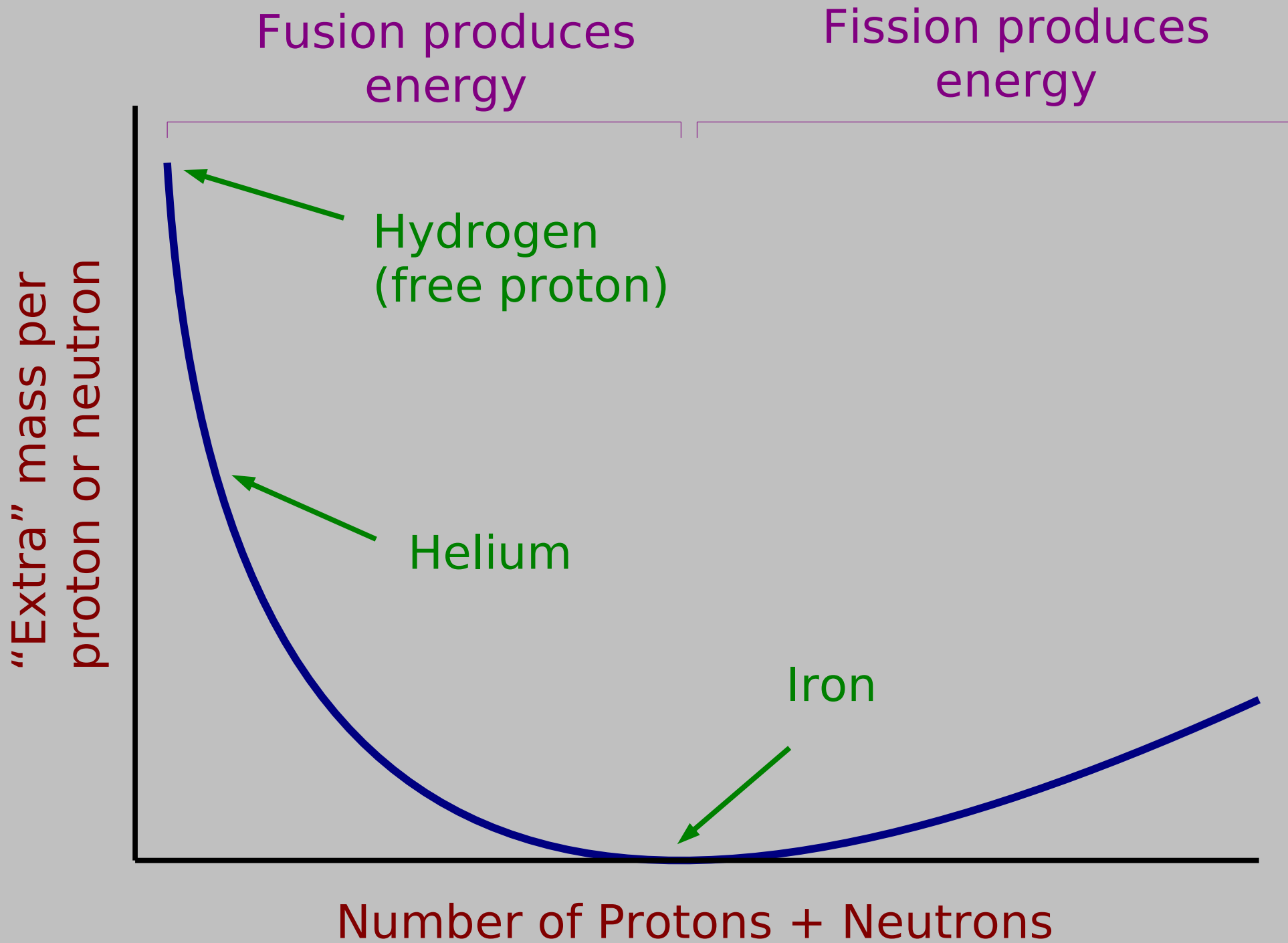
A Billions (10^9) of years

B Millions (10^6) of years

C Thousands (10^3) of years

D Just a few years old

E It would burn out in a few days



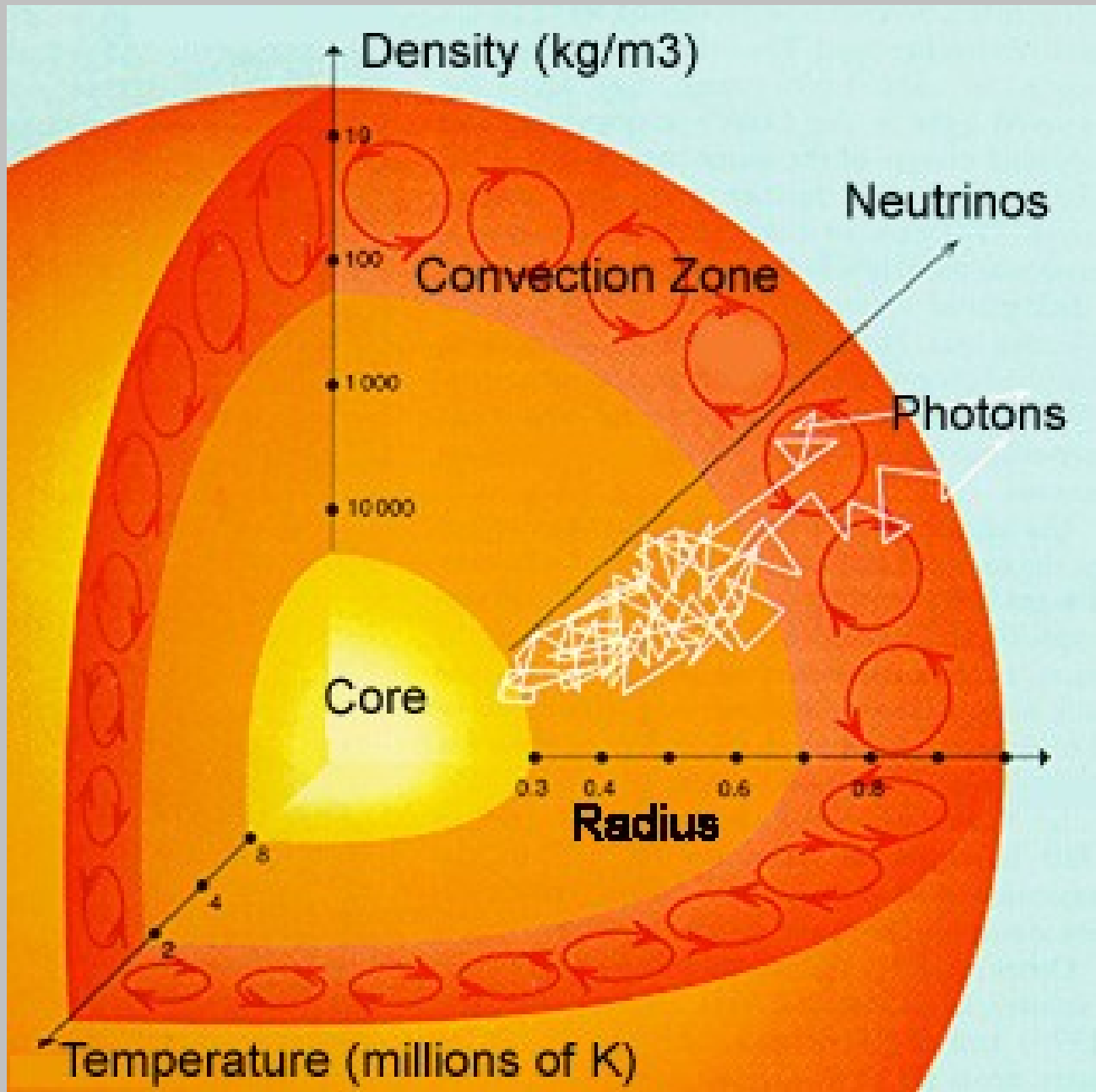


Image: CSE, SSL, UCB

How do we know that the Sun is powered via fusion?

- Fusion is the only plausible energy generation mechanism that can keep the Sun around for the 4.6 billion years we know it has been here.
- Detailed models of fusion and the interior structure of the Sun can explain the temperature and luminosity of the Sun as we observe it.



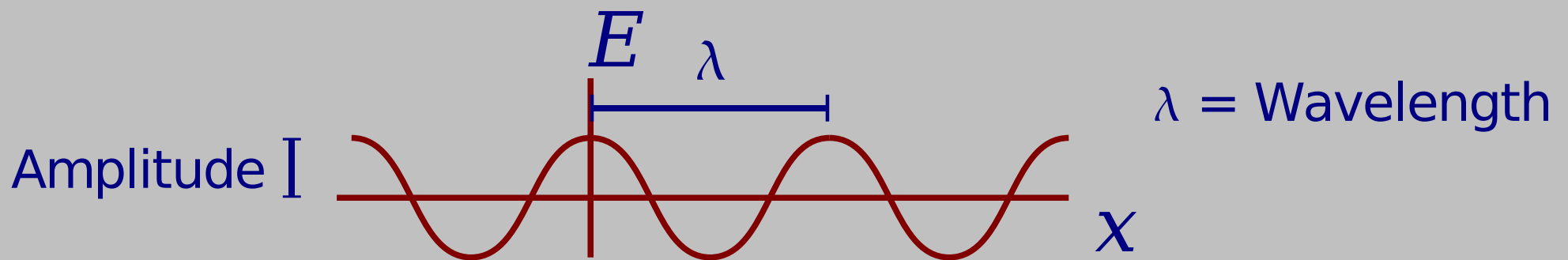
- We have directly observed the neutrinos from the Sun, and they match what is predicted!

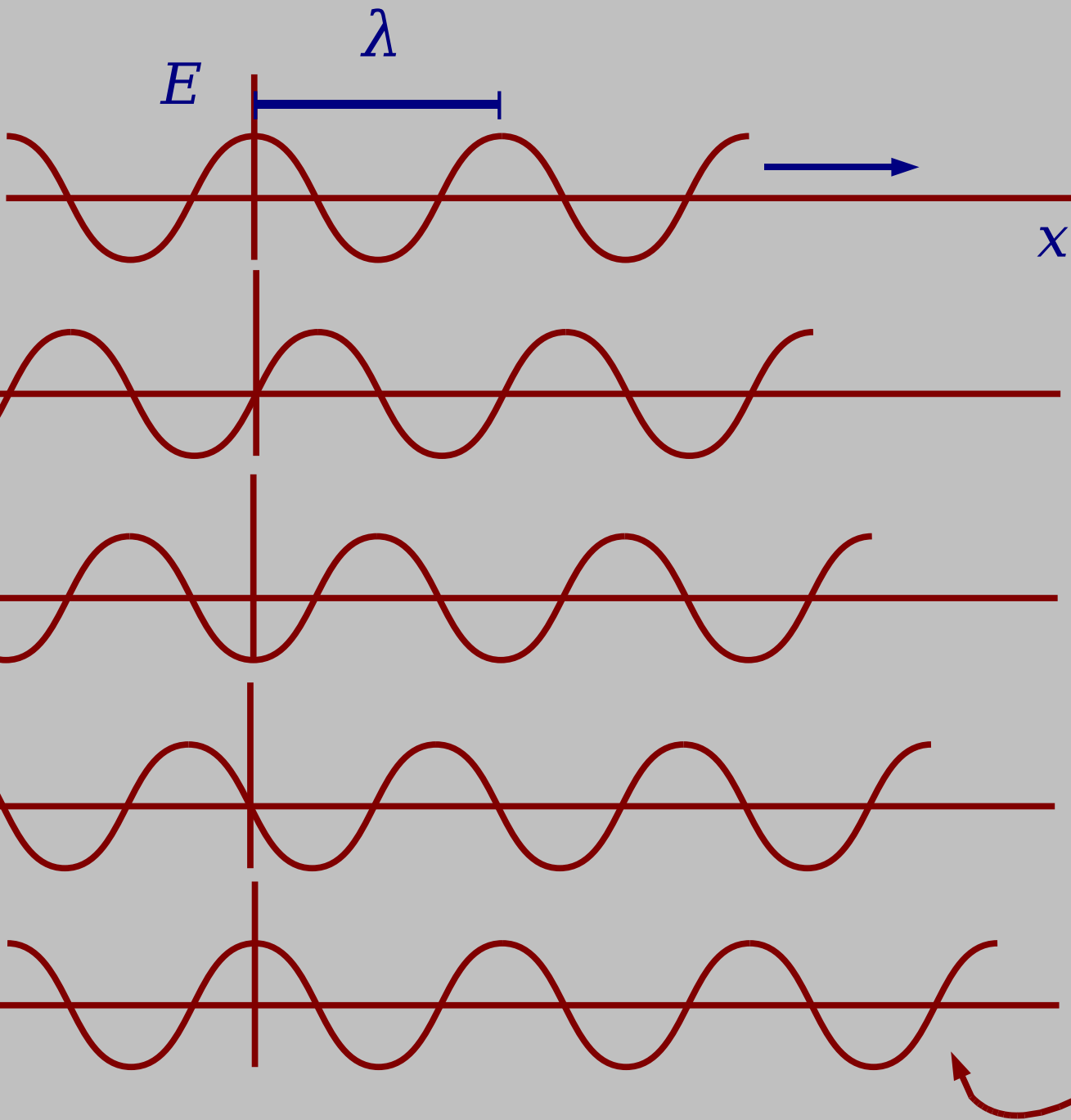
(Note : “Solar Neutrino Problem” is solved)

Light = Electromagnetic Wave

Oscillations of the Electromagnetic (E-M) Field

At one moment in time, the electric field E varies with position:





Initially

...later

...even later

...even more later

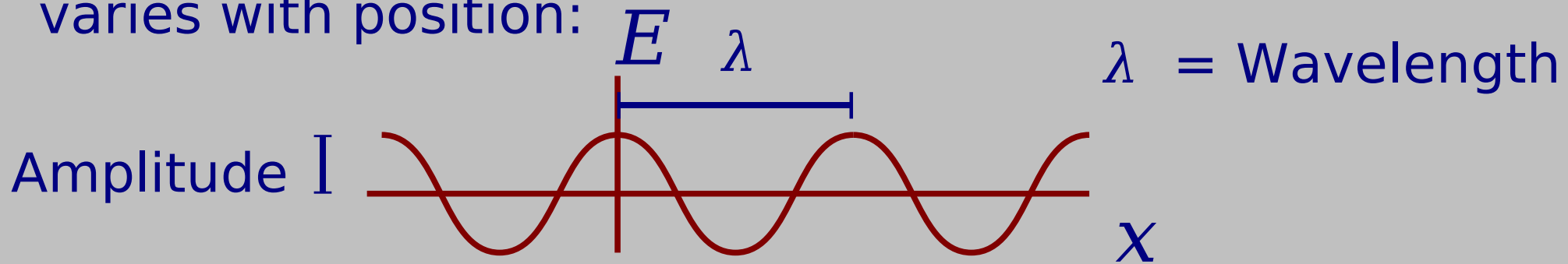
...yet even more later

Wave has advanced
one wavelength (λ)

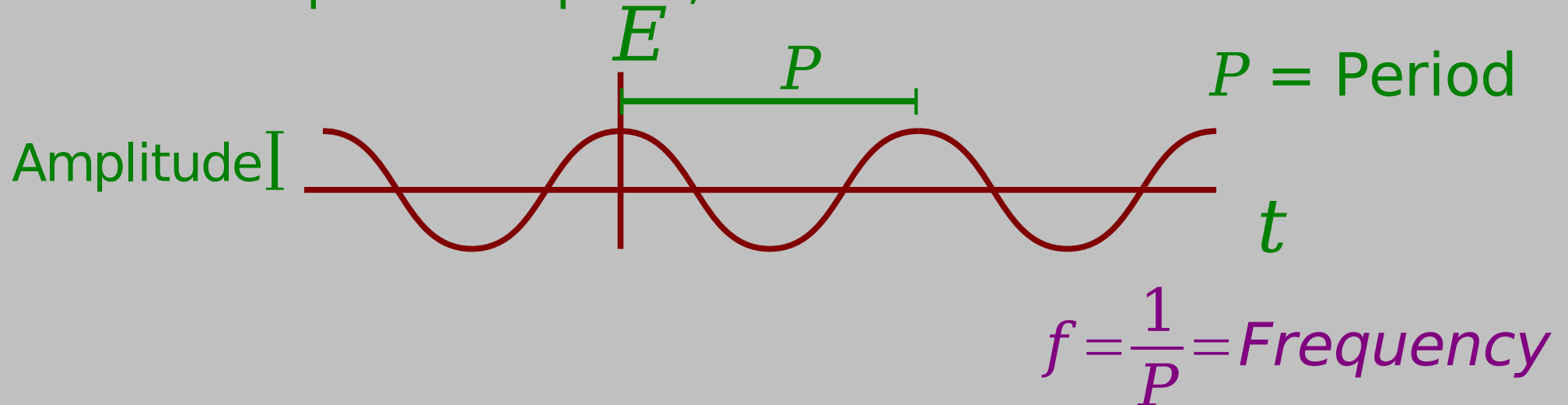
Light = Electromagnetic Wave

Oscillations of the Electromagnetic (E-M) Field

At one moment in time, the electric field E varies with position:



At one point in space, E varies with time:



How long does it take a light wave to move the distance of one wavelength?

amount = rate × time

$$\lambda = c t$$

$$t = \frac{\lambda}{c}$$

c = speed of light
= 3.00×10^8 m/s

This time is also the *Period P*

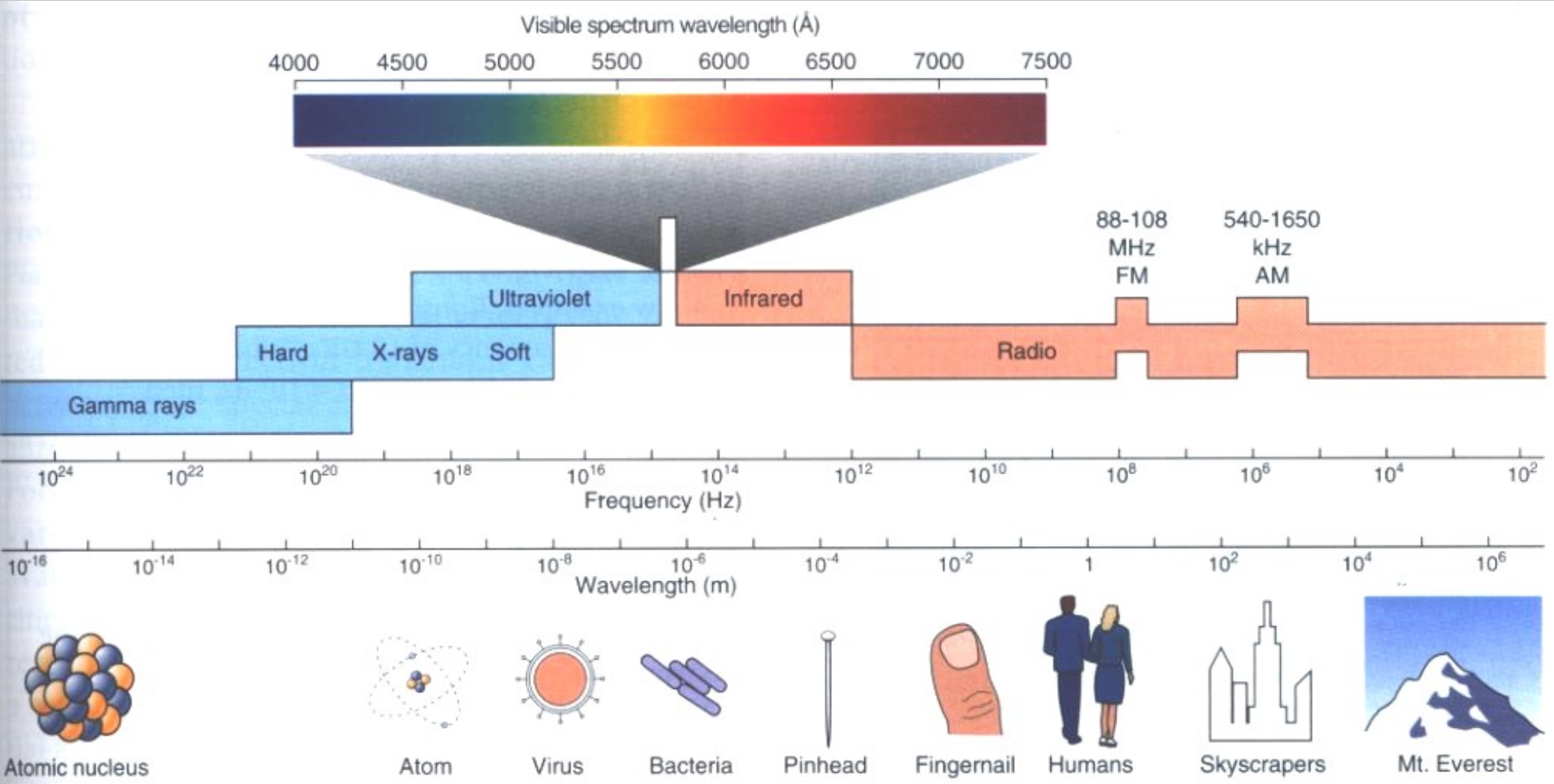
$$f = \frac{1}{P}$$

$$\frac{1}{f} = \frac{\lambda}{c}$$

$$\lambda f = c$$

$$f = \frac{c}{\lambda}$$

$$\lambda = \frac{c}{f}$$



Red light has wavelength $\lambda = 6700 \text{ \AA}$. What is the frequency of red light?
($1 \text{ \AA} = 10^{-10} \text{ m}$.)

A $1.5 \times 10^{-4} \text{ Hz}$

B $4.5 \times 10^4 \text{ Hz}$

C $4.5 \times 10^{14} \text{ Hz}$

D It is impossible to say from the information provided.