Next example:

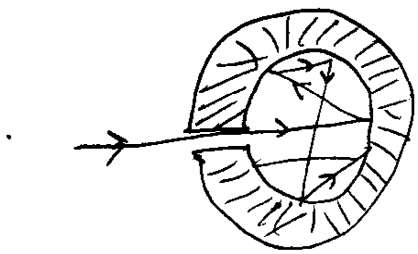
BLACKBODY RADIATION

"Blackbody" is an object that absorbs 100% of all EM radiation incident on it.

Normally, what we think is black, is not exactly black. E.g., one of the "blackest" thing known, soot, absorbs only about 95% of impinging light.

SUN is a much better example of a blackbody (this is not a joke!).

A much better blackbody than sooth is a hollow object ("cavity") with a tiny hole:



Light inside undergoes multiple reflections... The chance that a ray will exit again are tiny...

The exit of the opening is a very good practical example of a blackbody.

(For the same reason, an open window seen from outside in sunny weather looks black).

A Blackbody not only absorbs radiation - it also radiates energy.
(otherwise, the impinging radiation would heat it up and up and up... To maintain equilibrium, the absorbed energy must be re-radiated).

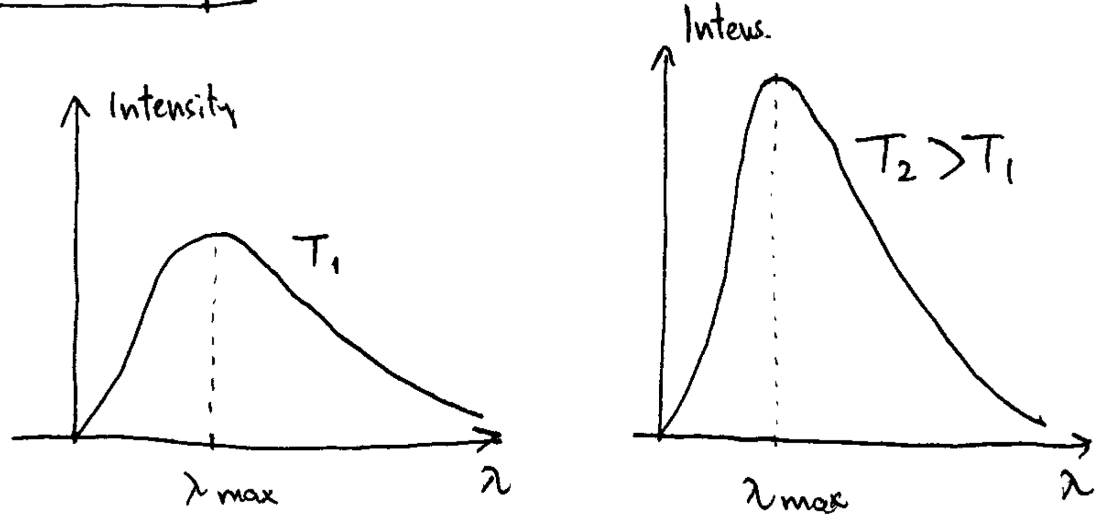
Blackbodies radiate energy even at room temperature (actually, at all temperatures >0).

At room temperature, the radiated energy is still in the invisible wavelength range.

But when heated up to several hundred Kelvins over room temperature, they start glowing red... At higher T, they become orange, yellow, and so on.

At the end of XIX century, physicists started investigating the blackbody radiation.

They found that the spectral distribution of the wavelengths always was of the same shape:



With increasing T, the maximum shifted to shorter wavelengths.

But essentially, it was always the same functional form.

The explanation of the blackbody spectrum shape became a major challenge for physicists at the end of the XIX century. After many unsuccessful attempts based on classical physics, a German scientist, Max Planck, applied the first quantum model in the history of physics, and he obtained a function that remarkably well desribed the spectrum.

Planck assumed that the energy is absorbed and re-emitted by oscillating atoms in the blackbody. In addition, he assumed that it can be absorbed/re-emitted only in discrete bundles (portions?) called quanta. ~~Each~~ An individual quantum, according to Planck, has the energy $\varepsilon = h\nu$, where ν is the radiation frequency, and h is a certain constant (now we call it the "Planck constant").

Planck's result for the spectrum shape was (in terms of wavelength λ):

$$R(\lambda) = \left(\frac{c}{4}\right)\left(\frac{8\pi}{\lambda^4}\right)\left[\left(\frac{hc}{\lambda}\right)\frac{1}{e^{hc/\lambda kT}-1}\right]$$

where c – speed of light, k – Boltzmann constant.

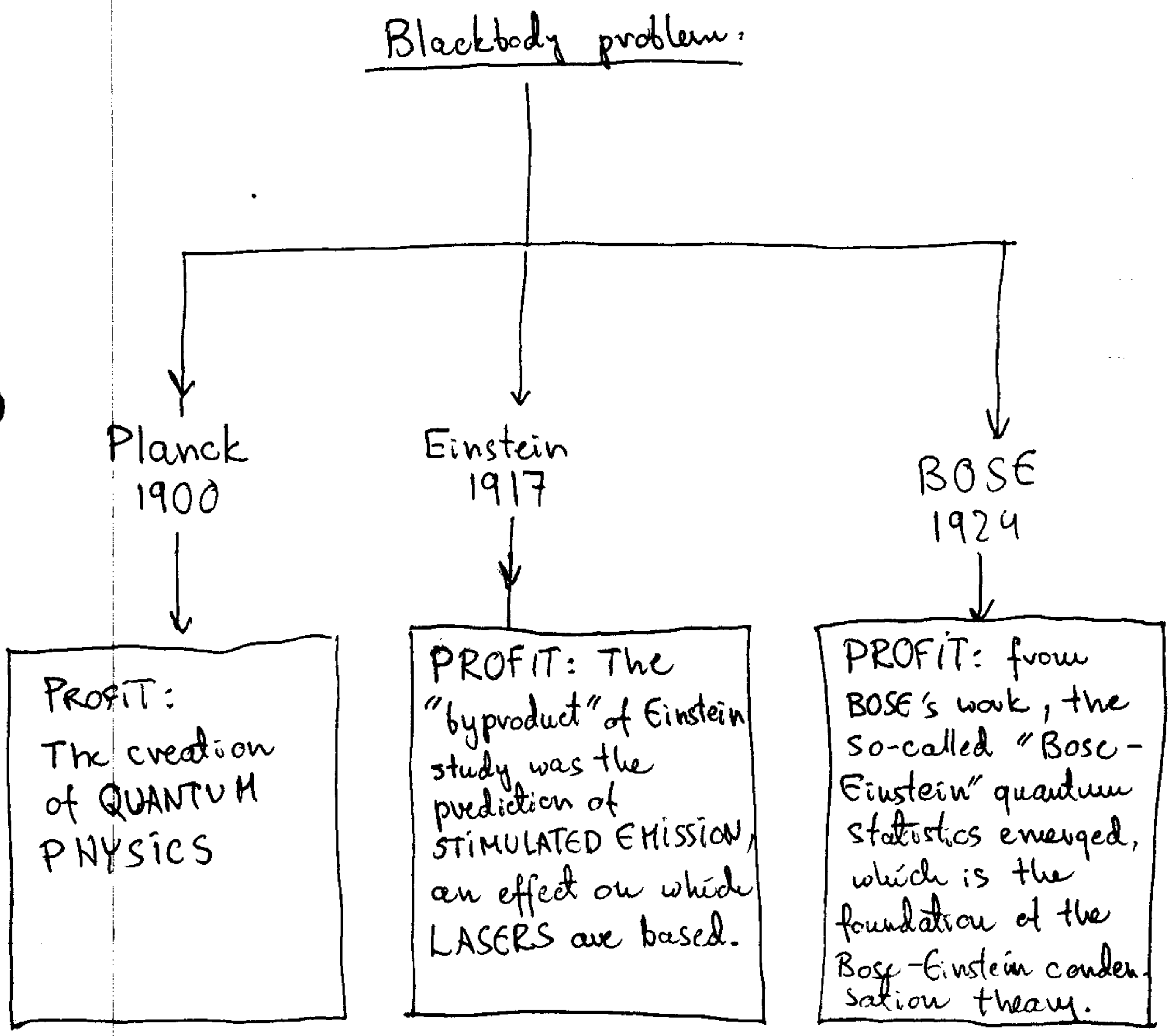
<u>THREE TIMES</u> in the history of physics the blackbody radiation problem was "attacked", each time using a different approach.

Einstein did not like the method Planck used. In 1917 he derived his own formula using completely different assumptions – and obtained an identical result as Planck did.

Again, in 1924 a young Indian physicist, Satyendra Nath BOSE, felt unhappy with Planck's approach – and he used yet another approach. Again, he obtained a result that was identical with the Planck's one.

SO WHAT ?!!! – if Einstein's and ~~[illegible]~~'s Bose's results were the same as Planck's, why do we mention them?

Well, because... All those three independent studies not only produced a correct description of the blackbody spectrum, but led to MAJOR DISCOVERIES:



BUT WHAT IS THE CONCLUSION FROM THE "BLACKBODY STORY"? Is light a wave, or particlelike?

- In Planck's model, only the energies of the atomic "oscillators" were quantized. Hence, Planck's theory is <u>still consistent with the wave theory</u> of light

- In his 1917 theory, Einstein used (both) "light quanta" and quantized oscillators. So, this theory supports the particlelike nature of light.

- In Bose's theory, only "light quanta" are considered, the oscillators are not relevant – – so, the theory also supports the particle-like nature.

Altogether, the blackbody radiation theories strongly support the particle-like nature of light.