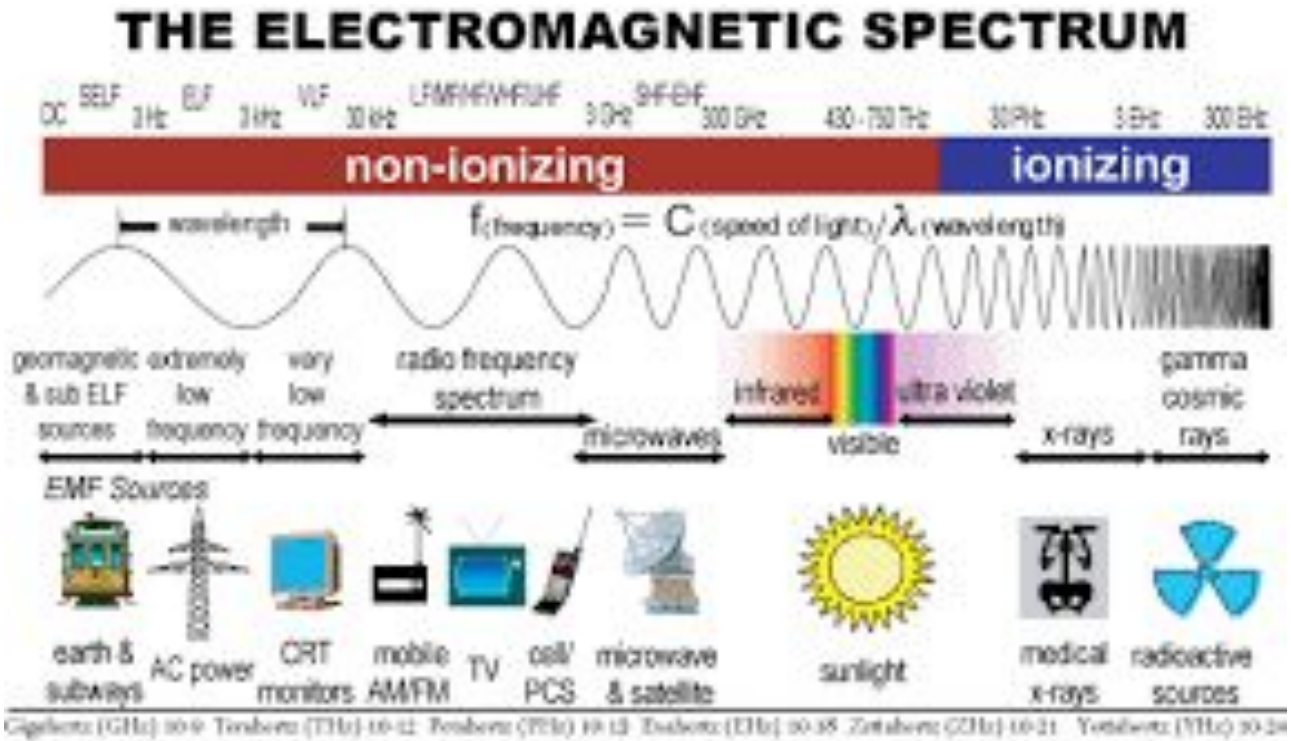
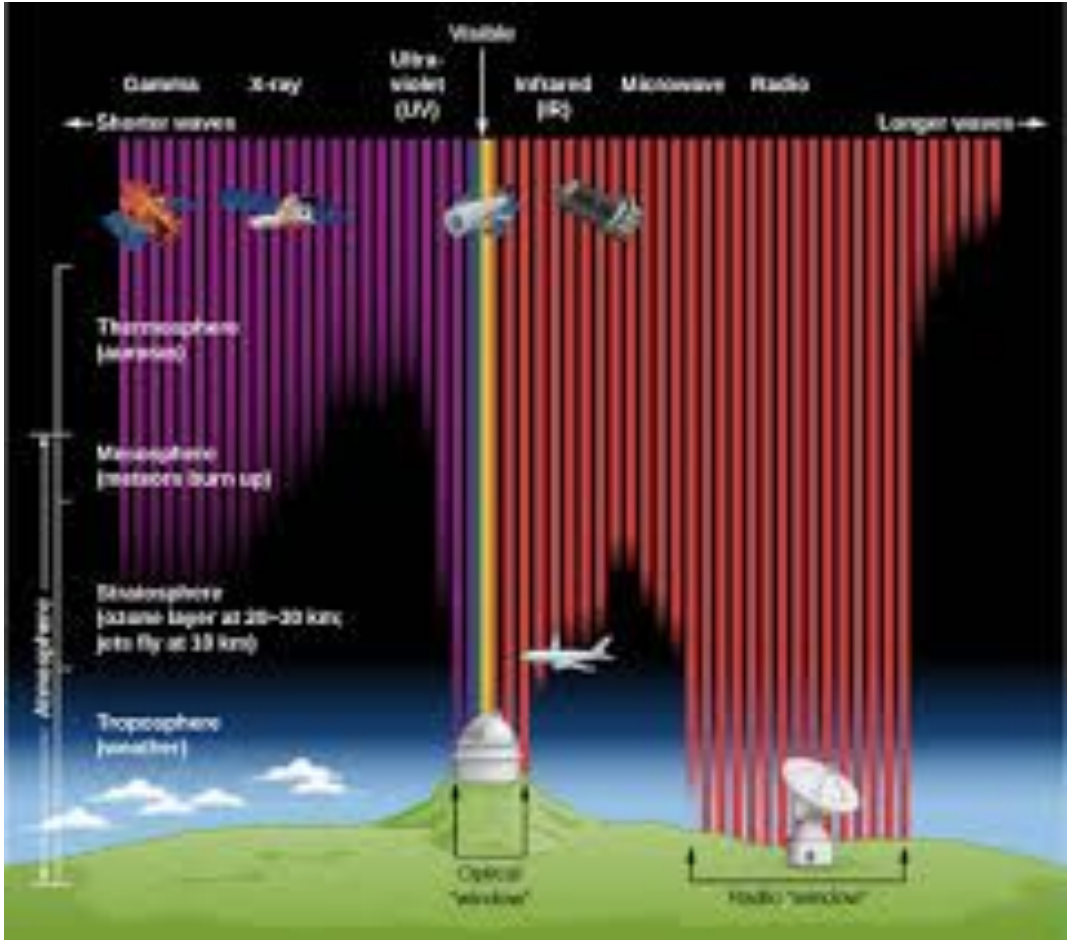
3.1 Thermal Physics and Statistical Mechanics
3.1.1 Thermal Physics and Statistical Mechanics (Theory)

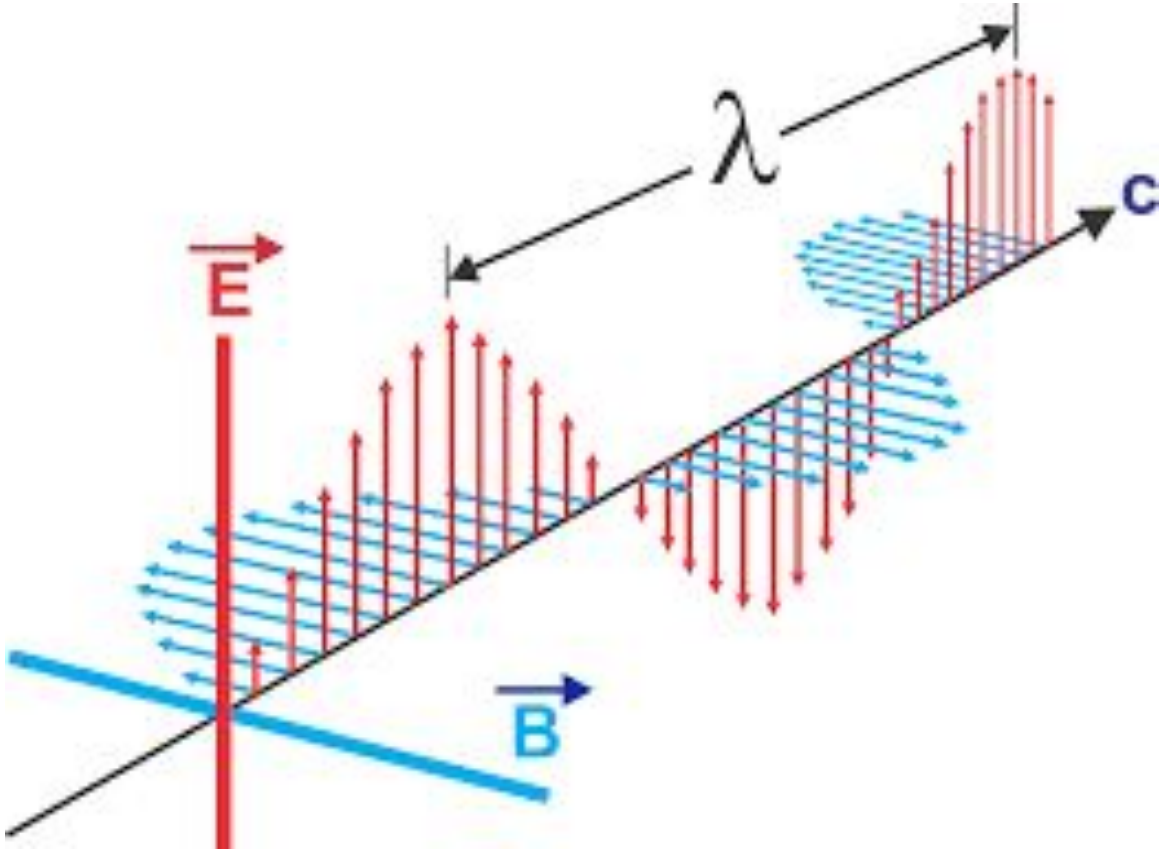
4. Theory of Radiation 8 Lectures

(a) Blackbody radiation, Spectral distribution, Concept of Energy Density, Derivation of Planck's law, Deduction of Wien's distribution law, Rayleigh- Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

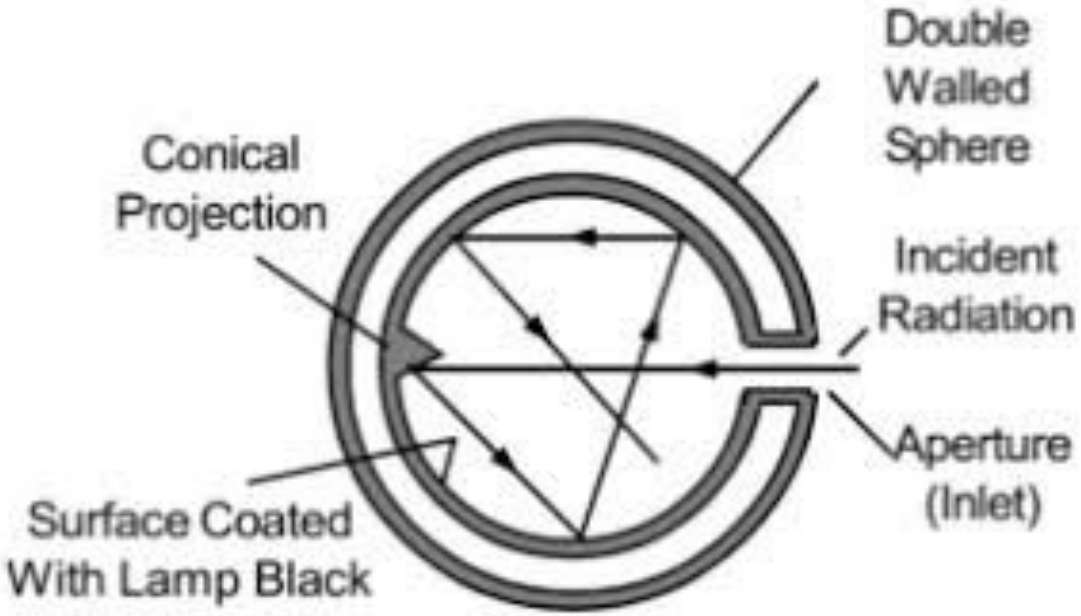
Electromagnetic waves

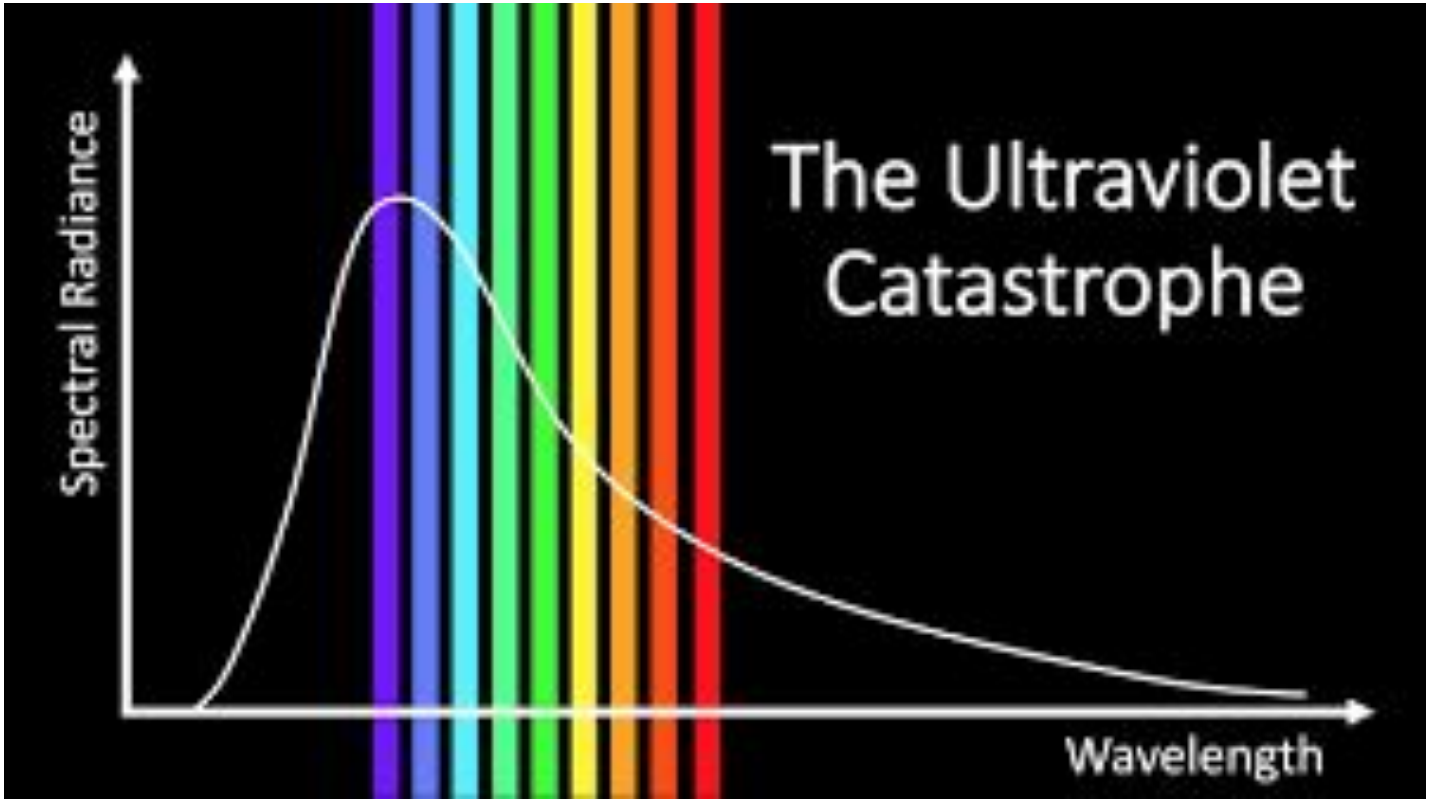



Visible
Gamma
X-ray
Ultra-violet (UV)
Infrared (IR)
Microwave
Radio
Shorter waves
Longer waves
Thermosphere (aurorae)
Mesosphere (meteors burn up)
Stratosphere (ozone layer at 20–30 km; jets fly at 10 km)
Troposphere (weather)
Atmosphere
Optical "window"
Radio "window"

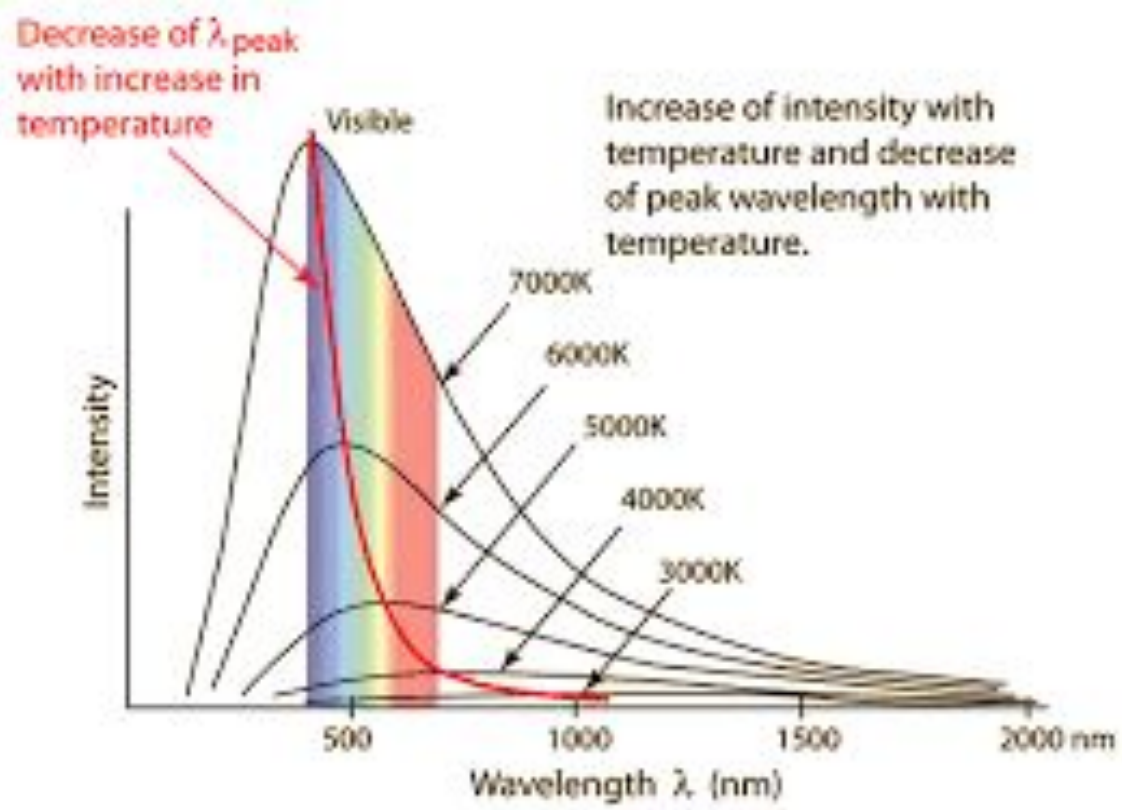

λ
c
E
B

Black body


Double
Walled
Sphere
Conical
Projection
Incident
Radiation
Aperture
(Inlet)
Surface Coated
With Lamp Black

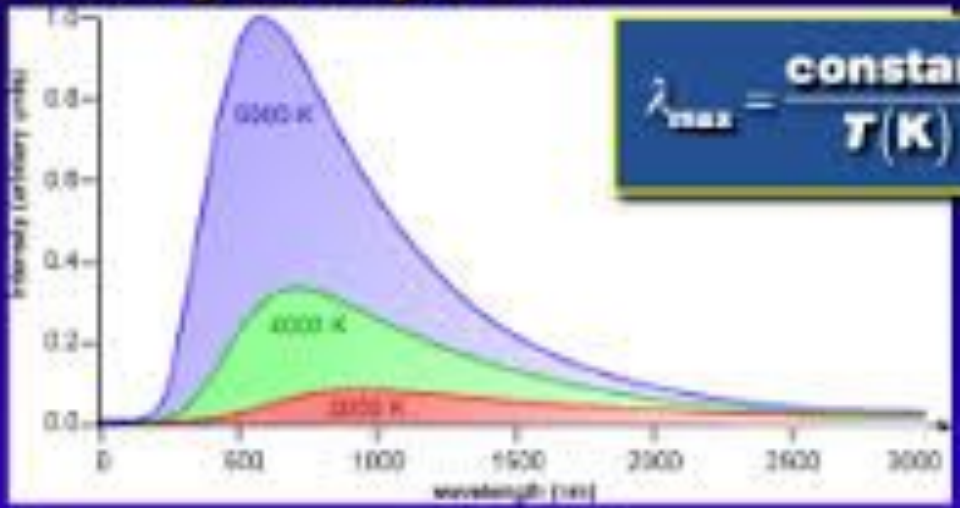

The Ultraviolet Catastrophe
Spectral Radiance
Wavelength

Wien”s lawe


Decrease of λ peak with increase in temperature
Visible
Increase of intensity with temperature and decrease of peak wavelength with temperature.
7000K
6000K
5000K
4000K
3000K
Intensity
500
1000
1500
2000 nm
Wavelength λ (nm)

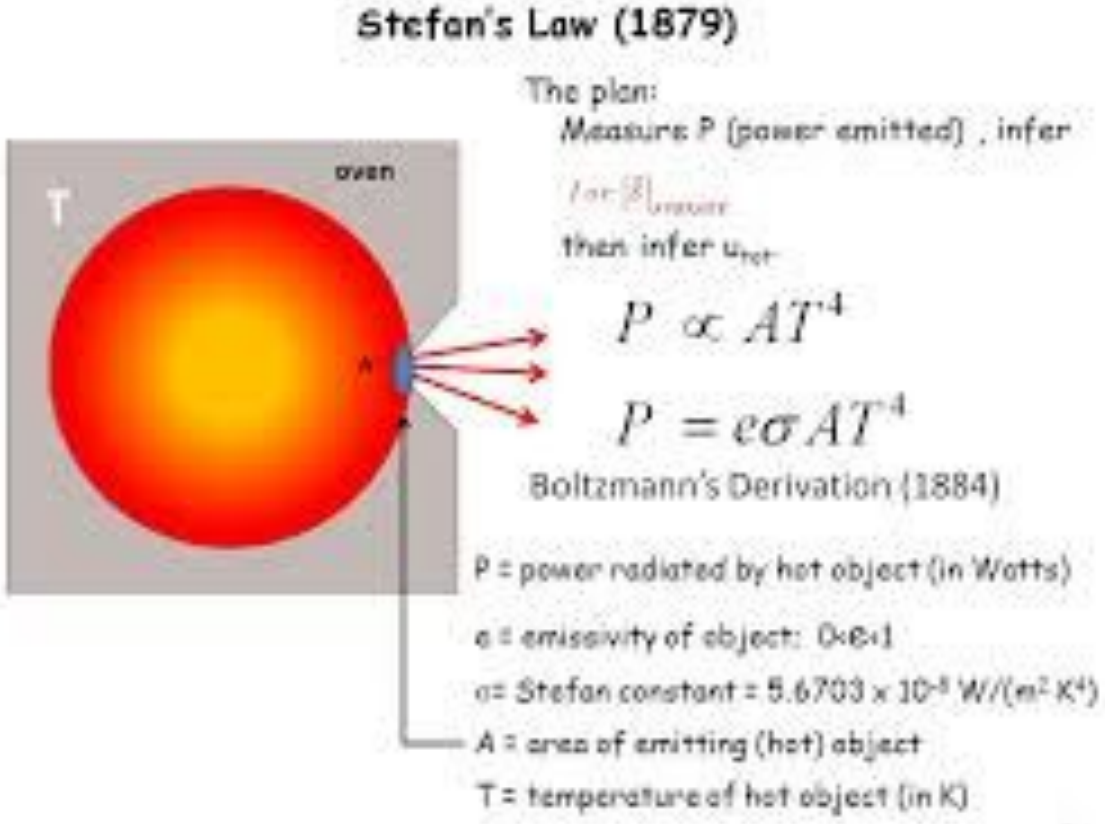
Wien's Law

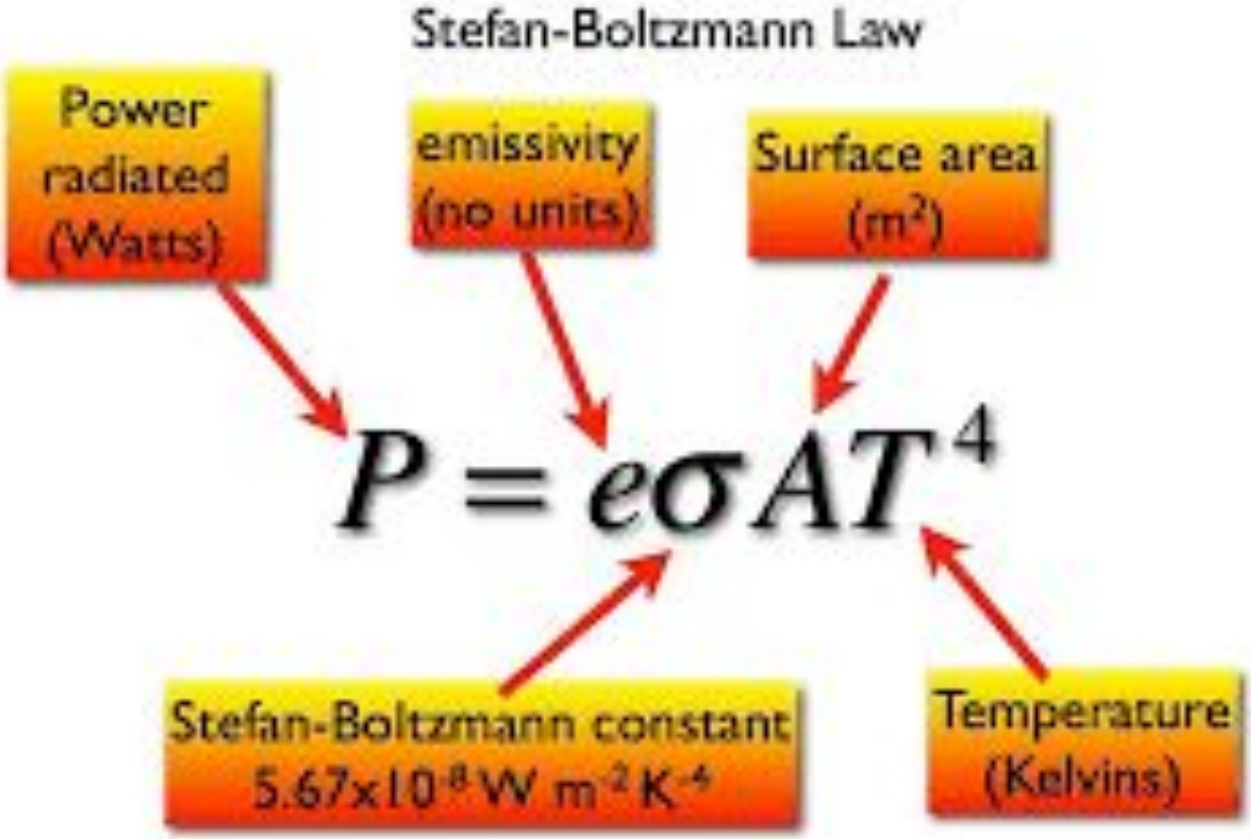
- A blackbody emits EMR such that the wavelength of maximum intensity (λ_{max}) is inversely proportional to the blackbody's temperature



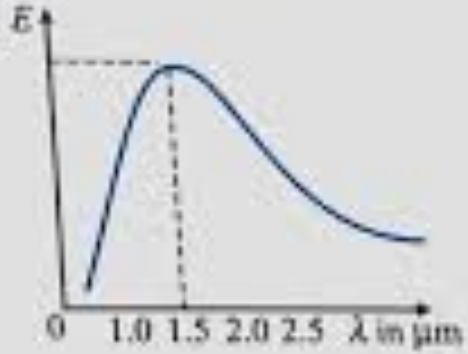
$$\lambda_{max} = \frac{\text{constant}}{T(\text{K})}$$

Stefan’s law

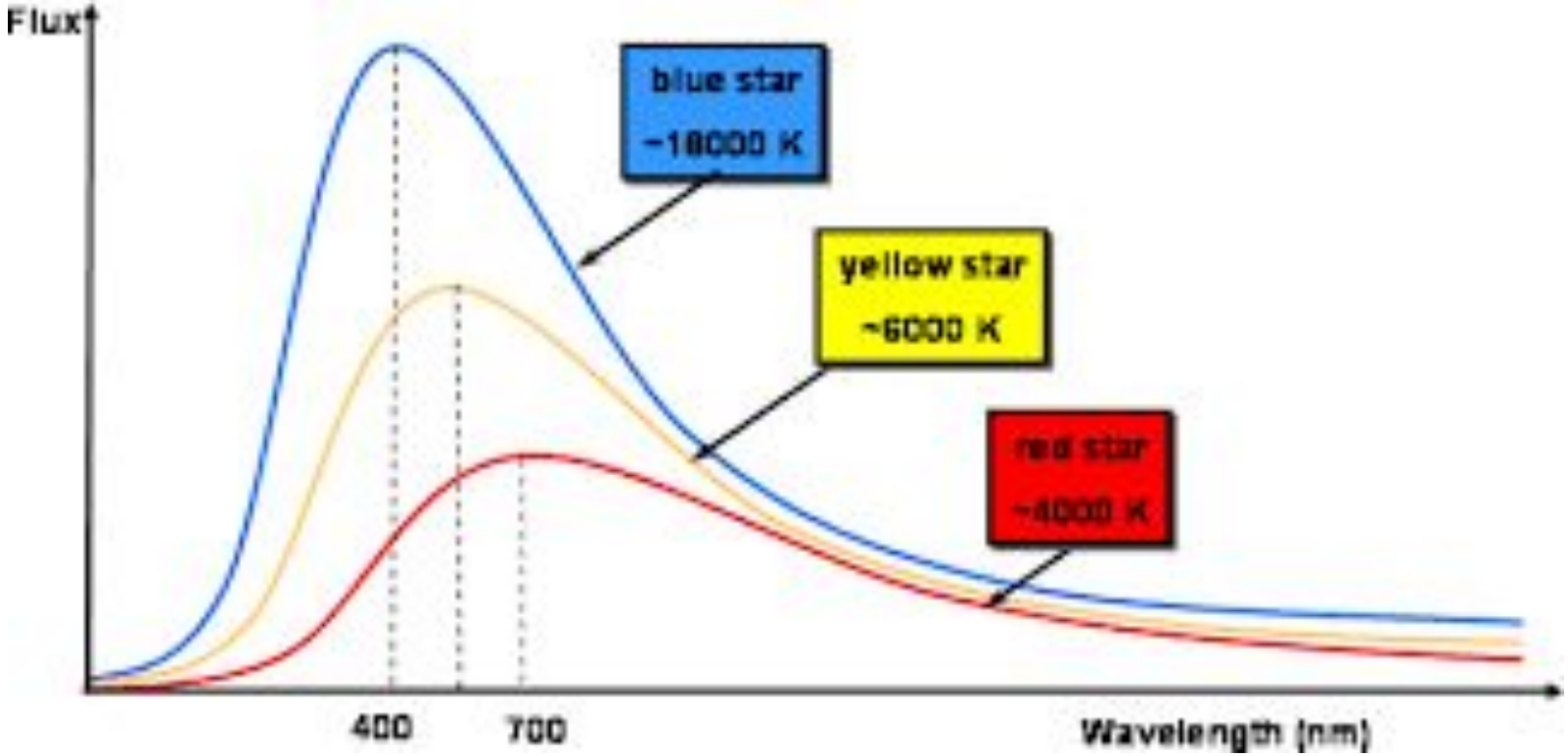

Stefan's Law (1879)
The plan:
Measure P (power emitted) , infer
then infer u_{tot}
$P \propto AT^4$
$P = e\sigma AT^4$
Boltzmann's Derivation (1884)
oven
T
A
P = power radiated by hot object (in Watts)
e = emissivity of object: 0<e<1
σ= Stefan constant = 5.6703 x 10⁻⁸ W/(m² K⁴)
A = area of emitting (hot) object
T = temperature of hot object (in K)

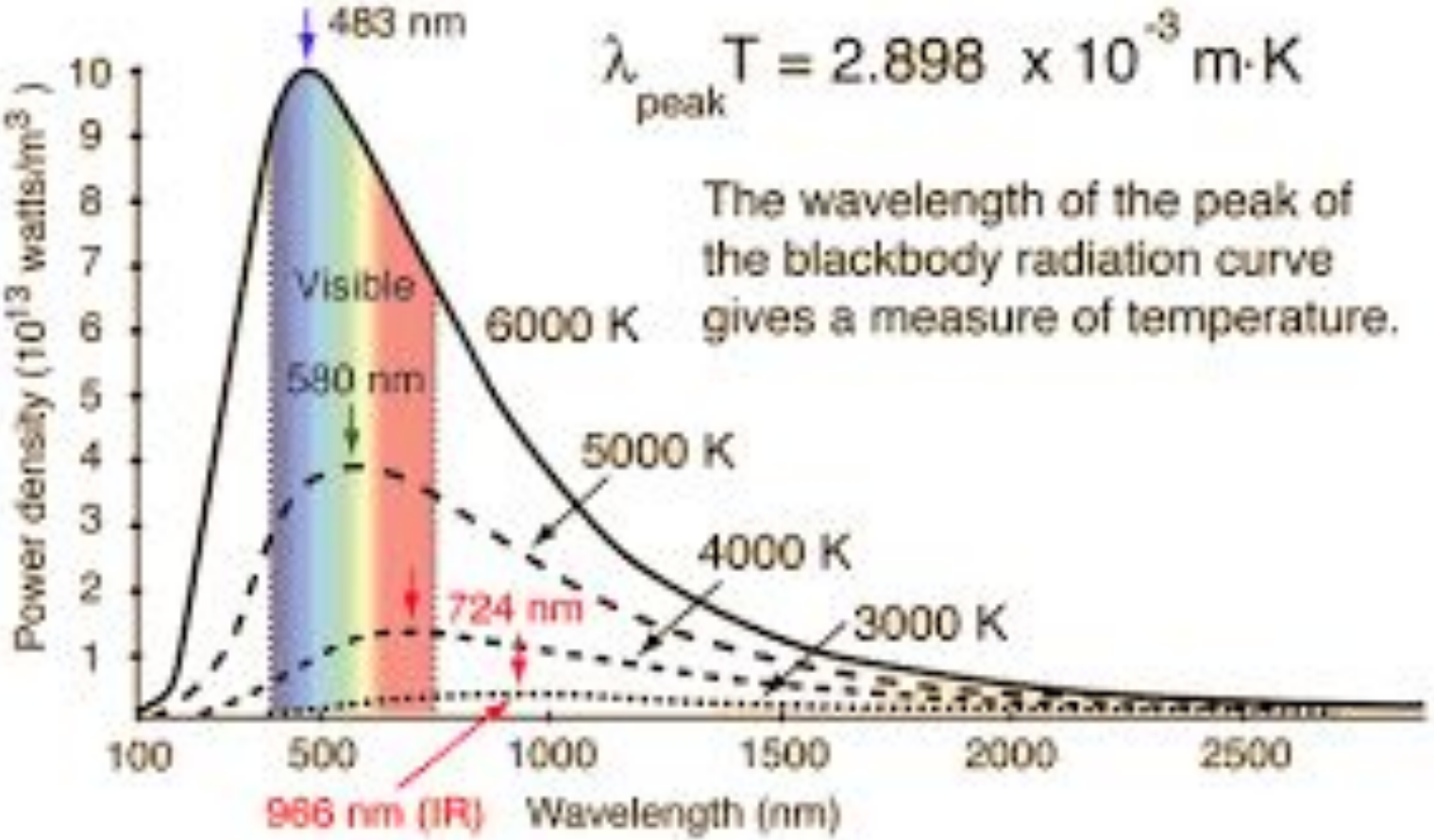

Stefan-Boltzmann Law
Power radiated (Watts)
emissivity (no units)
Surface area (m^2)
$P = e\sigma AT^4$
Stefan-Boltzmann constant 5.67×10^{-8} W m^{-2} K^{-4}
Temperature (Kelvins)

4. In the figure, the distribution of energy density of the radiation emitted by a black body at a given temperature is shown. The possible temperature of the black body is



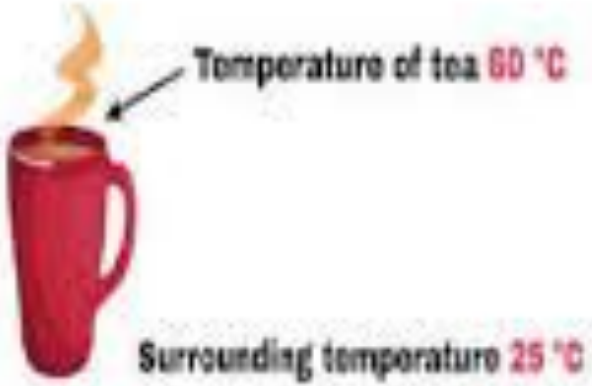
(1) 1500 K
(2) 2000 K
(3) 2500 K
(4) 3000 K


Flux
blue star
~18000 K
yellow star
~6000 K
red star
~4000 K
400
700
Wavelength (nm)


483 nm
$\lambda_{peak} T = 2.898 \times 10^{-3}$ m·K
The wavelength of the peak of the blackbody radiation curve gives a measure of temperature.
Power density (10^{13} watts/m^3)
Visible
590 nm
6000 K
5000 K
4000 K
3000 K
724 nm
986 nm (IR)
Wavelength (nm)
100
500
1000
1500
2000
2500
1
2
3
4
5
6
7
8
9
10

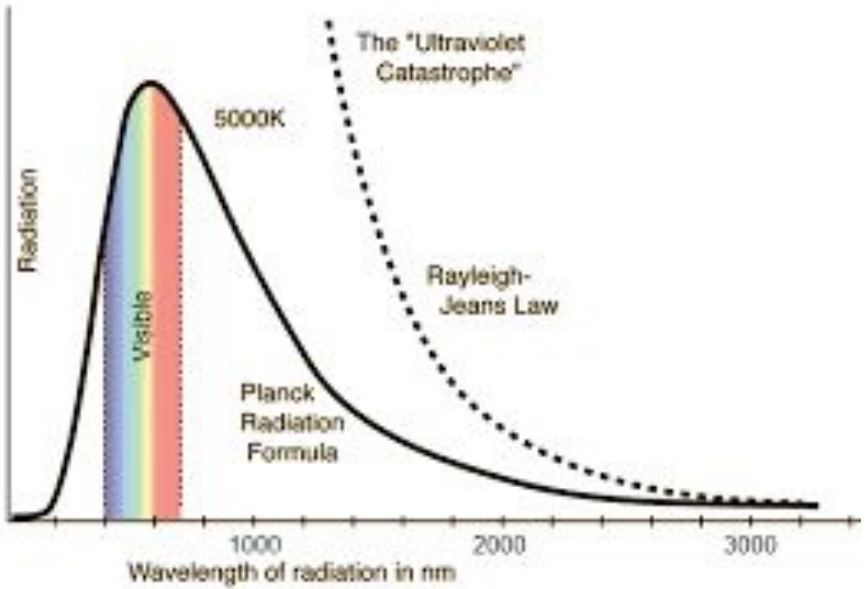
Newton's law of cooling

Before



After some time,

Raleigh jean's law



Orion constellation