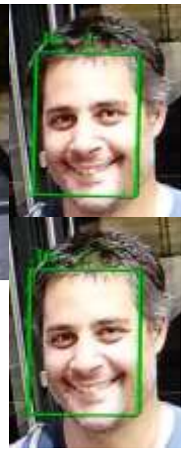
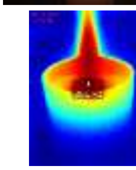


Thermal radiation characteristics and description; emission of the human body, medical applications, infra-diagnostics, Polarization of light.

Gusztáv Schay

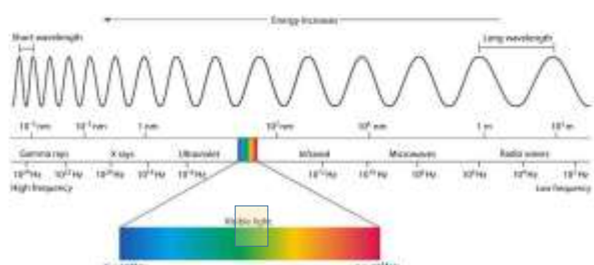
Thermal emission

GLOWING HOT



Hot objects emit light.

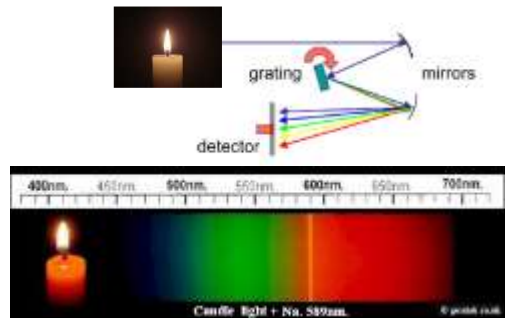
Maybe even colder objects do the same?



We only see as “Light” a very limited range of the full electromagnetic wave spectrum. But light is also all the others!

ALL objects generate light, IF their temperature is above 0 K.

This is called thermal radiation.



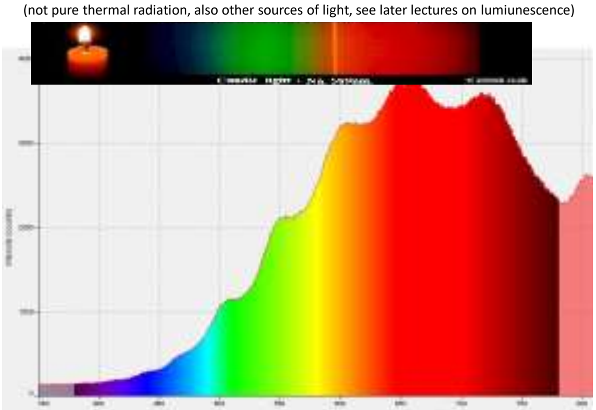
Source: the thermal motion of the atoms, molecules, as they all have charges inside.
Basic Physics course: an accelerating charge creates an electromagnetic field.

Just for fun: it can be exactly calculated, but this is NOT required here ;)

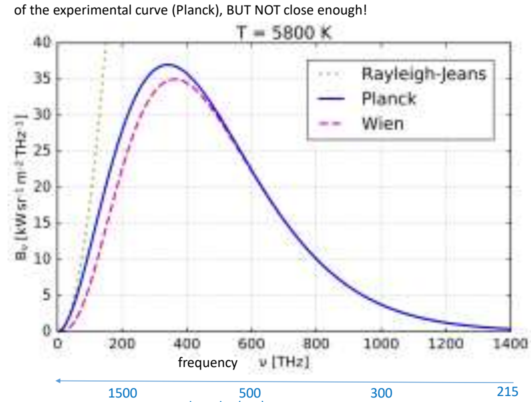
$\mathbf{E}_{rad}(\mathbf{r},t) = -[1/(4\pi\varepsilon_0)]*[q/(c^2r')]*\mathbf{a}_{perp}(t - r'/c)$

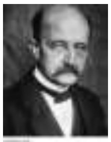
charge — acceleration — speed of light: $3\cdot10^8$ m/s

Emission spectrum of a candle flame
(not pure thermal radiation, also other sources of light, see later lectures on lumiunescence)



From classic physics, with a LOT of calculations it is possible to come quite close to the shape of the experimental curve (Planck), BUT NOT close enough!





Max Planck (~ 1900)

He could get the correct shape of the cuve ONLY IF he assumed that the energy of the light-waves is "packaged" into discrete values of h·f, which Einstein later coined as PHOTONS

$$E_n = nhf$$

← vibrational frequency (f); ← integer (n)

En is the energy of n photons together, all with the same frequency.
The accelerating charges produce photons with a given frequency

with this, he could get a formula which has the correct shape ☺

$$\rho(f,T)\,df = \frac{8\pi V f^2 df}{c^3}\frac{hf}{e^{hf/kT}-1}$$

Do NOT learn the formula itself!

Gustav Kirchhoff (1824-1887)

If an object absorbs light well, then it also emits light well.

The best emitter is then an absolute black body, which absorbs all light arriving onto the surface.

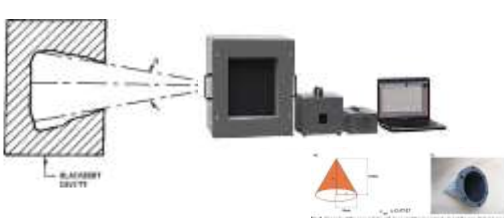
$$\alpha = \frac{J_{\text{absorbed}}}{J_{\text{total incident}}}$$

absor**pt**ance

n.B.: $A=\lg(J_0/J_{transmitted})$
this is the absor**b**ance

Total black body: α=1

This can be simulated by specially designed boxes with a hole.
The hole itself can act as a black body



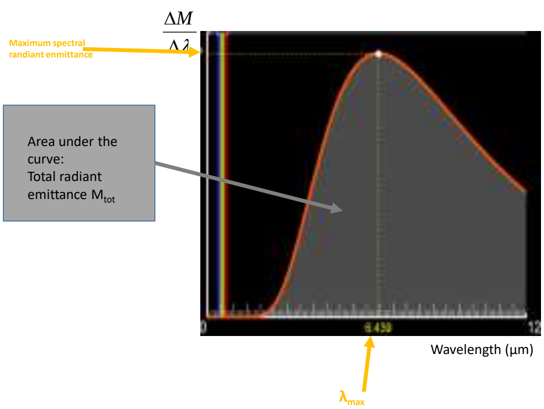
M: radiant emittance (W/m^2)
The emitted power on a unit surface of the emitter body.

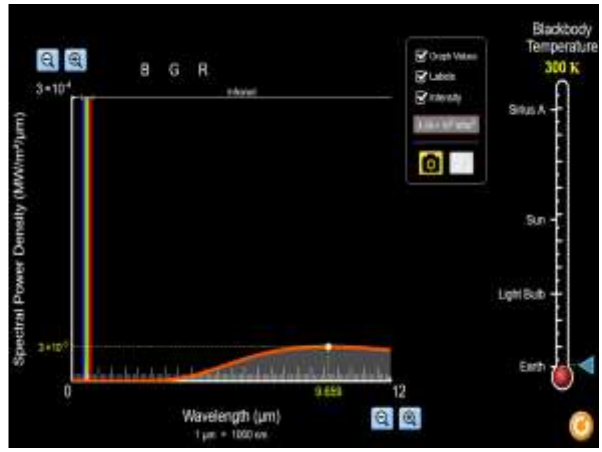
Kirchhoff's law: M/α is constant.

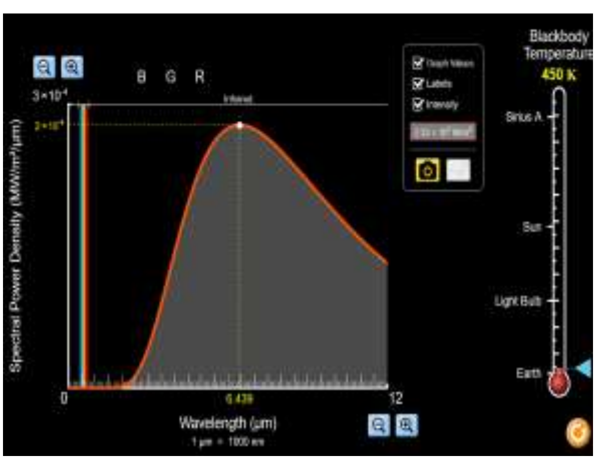
This means, if an object is absorbing all of the radiation, so α=1, then $M=M_{max}$

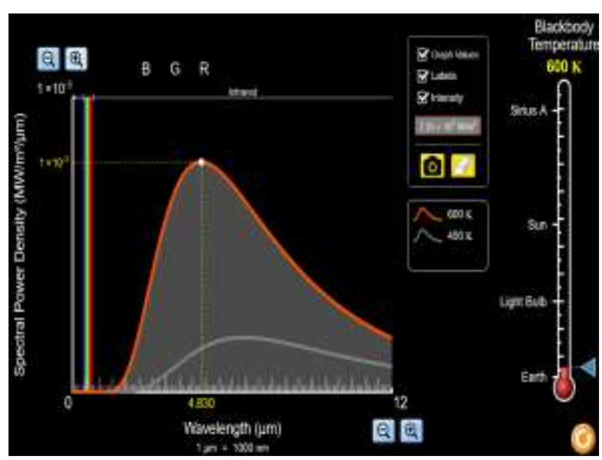
Both M and α depend on the frequency (or wavelength)!
(spectral radiant emittance, M_λ and spectral absorptance α_λ)

How close a body comes to the absolute black body


ΔM/Δλ
Maximum spectral randiant enmittance
Area under the curve: Total radiant emittance M_tot
0
6.430
12
Wavelength (μm)
λmax


Blackbody Temperature
300 K
B G R
3×10⁻⁴
Spectral Power Density (MW/m²/μm)
Sirius A
Sun
Light Bulb
Earth
0
9.659
12
Wavelength (μm)
1 μm = 1000 nm


Blackbody Temperature
450 K
B G R
3×10⁻⁴
Spectral Power Density (MW/m²/μm)
Sirius A
Sun
Light Bulb
Earth
0
6.439
12
Wavelength (μm)
1 μm = 1000 nm

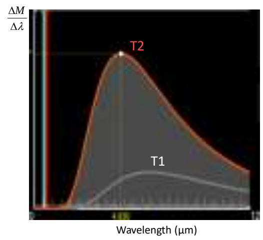

Blackbody Temperature
600 K
B G R
Spectral Power Density (MW/m²/μm)
600 K
450 K
Sirius A
Sun
Light Bulb
Earth
0
4.830
12
Wavelength (μm)
1 μm = 1000 nm

Two famous laws:

Wien's displacement law
$\lambda_{max} \cdot T = 2.898 \cdot 10^6$ K·nm (Wien's constant)

Stephan-Boltzmann's law
$M_{tot} = \sigma \cdot T^4$

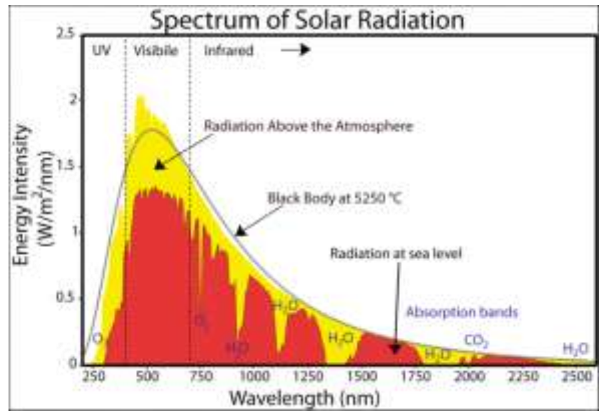
$\sigma = 5.7 \times 10^{-8} [\frac{W}{m^2 K^4}]$



$$\Delta M = \sigma (T^4_{object} - T^4_{environment})$$

W/m² ! K

Thermal equilibrium will also be reached through radiation energy exchange.



Heat energy exchange possibilities

+ Evaporation (Perspiration)

For an adult, approx. 2 m² skin area (at room temperature environment):

Radiation → $\approx 100W$

Conduction → $\leq 1W$

Convection → $\approx 10W$

Perspiration → $\approx 10W$

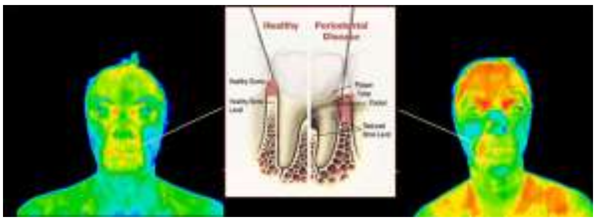
Most of the metabolic rate (2000kcal/day = 9MJ/day) is used up for radiative heat loss.

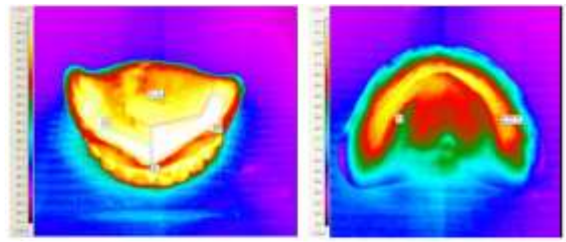
Stephan-Boltzmann's law
$M_{tot} = \sigma \cdot T^4$ $\sigma = 5.7 \times 10^{-8} [\frac{W}{m^2 K^4}]$

Wien's displacement law
$\lambda_{max} \cdot T = 2.898 \cdot 10^6$ K·nm (Wien's constant) → For human skin surface $\lambda_{max} = 7 \dots 15$ μm

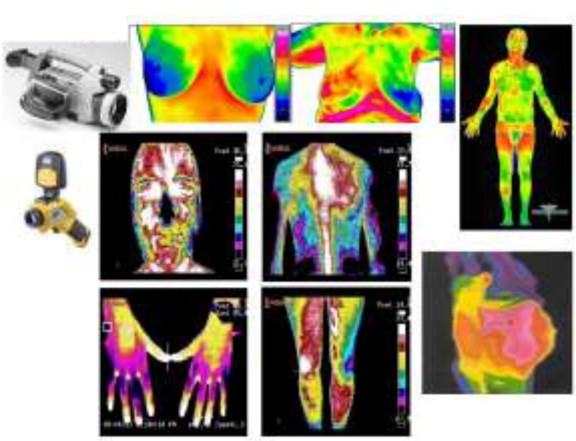
Thermal imaging and sensing is very sensitive!

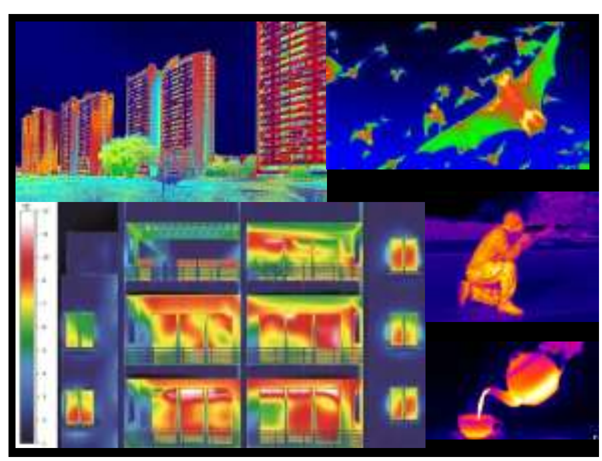
Inflammation, cancer, elevated metabolic rate can be detected.



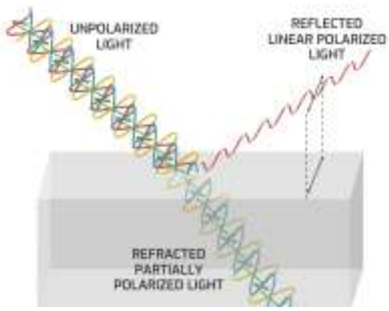


Thermograms of the denture after its removal from the oral cavity

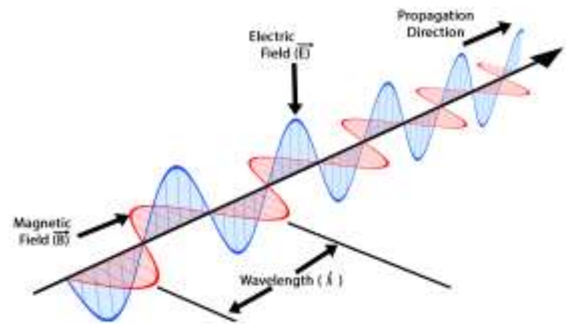


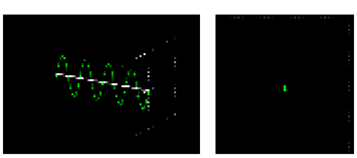


Polarization of light



Electromagnetic Wave



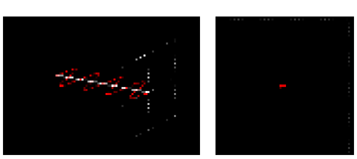


We usually only show the E-field vector, to make the drawing easier to read.

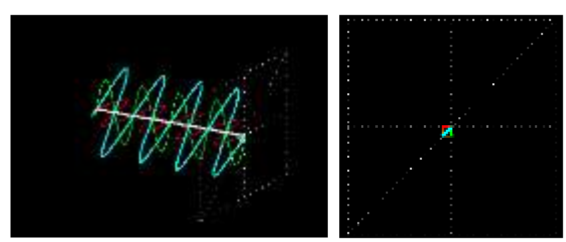
We do imagine the B-field vector to be there, since it is EM-wave!

Polarization is the direction of the E-field vector

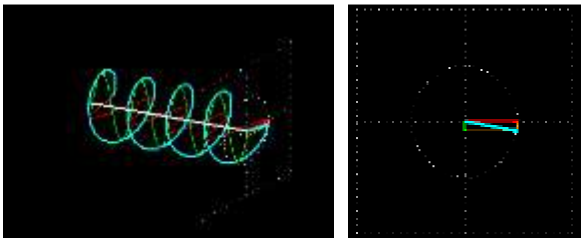
Linear polarized light: only one direction is possible. (more precisely, along one line)



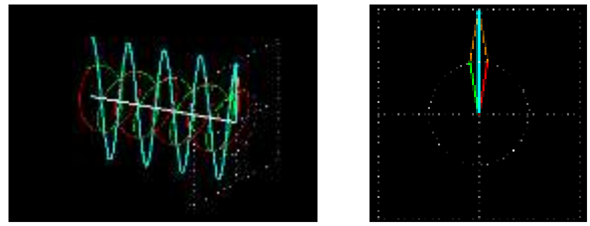
https://cddemo.szialab.org/



Superposition principle: waves can be freely added together, **the resulting E-field is the vectorial sum of the components**

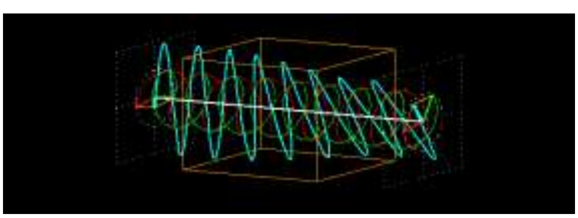


Circular polarized light: it can be the sum of two linear polarized lights.

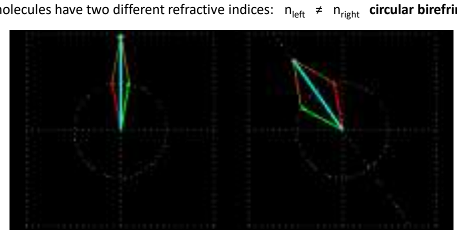


But linear polarized light can be the sum of two circular polarized lights.

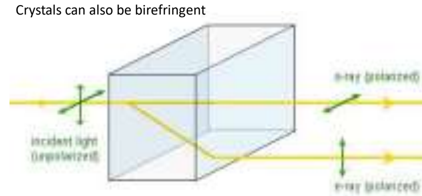
Vector algebra ☺



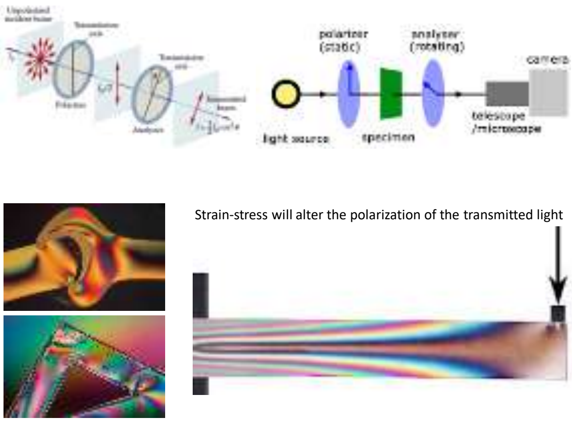
Chiral molecules have two different refractive indices: $n_{left} \neq n_{right}$ **circular birefringence**

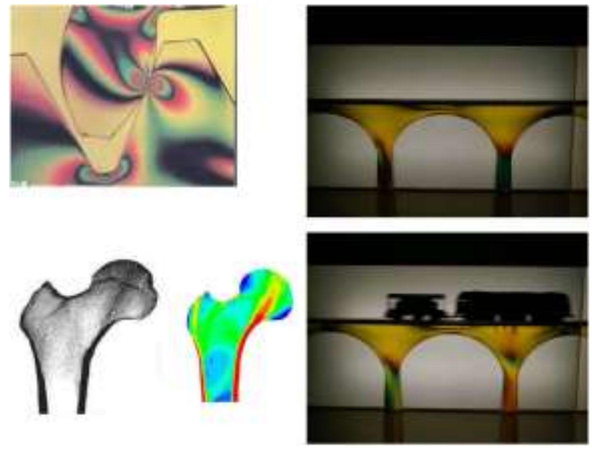


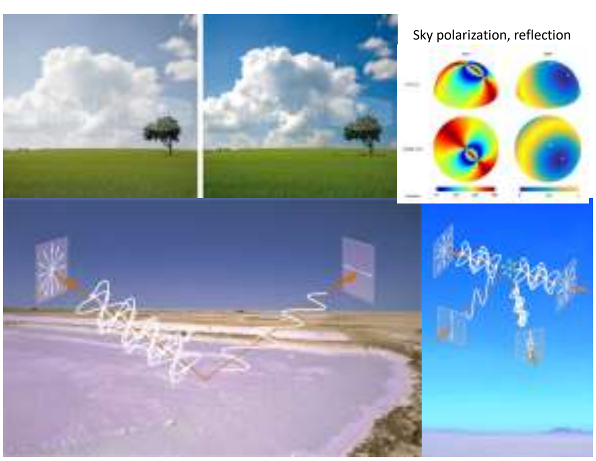
Crystals can also be birefringent

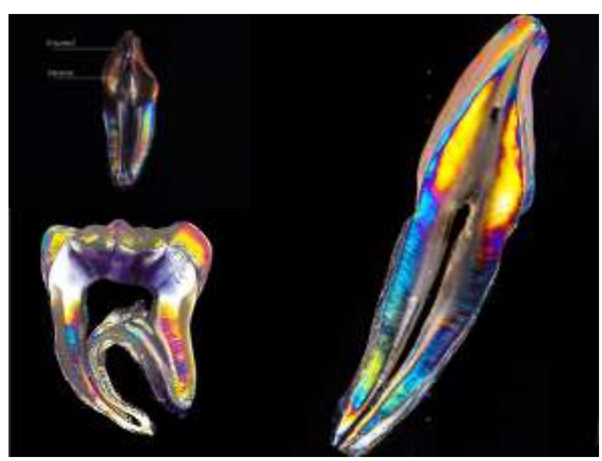


calcite


polarizer
(static)
analyzer
(rotating)
camera
light source
specimen
telescope
/microscope
Strain-stress will alter the polarization of the transmitted light




Sky polarization, reflection



Cross polarization dental photography

Color matching in prosthodontics