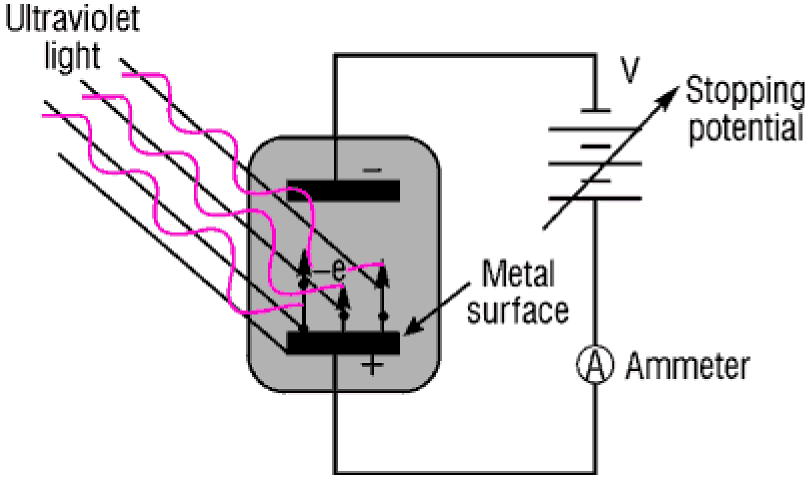
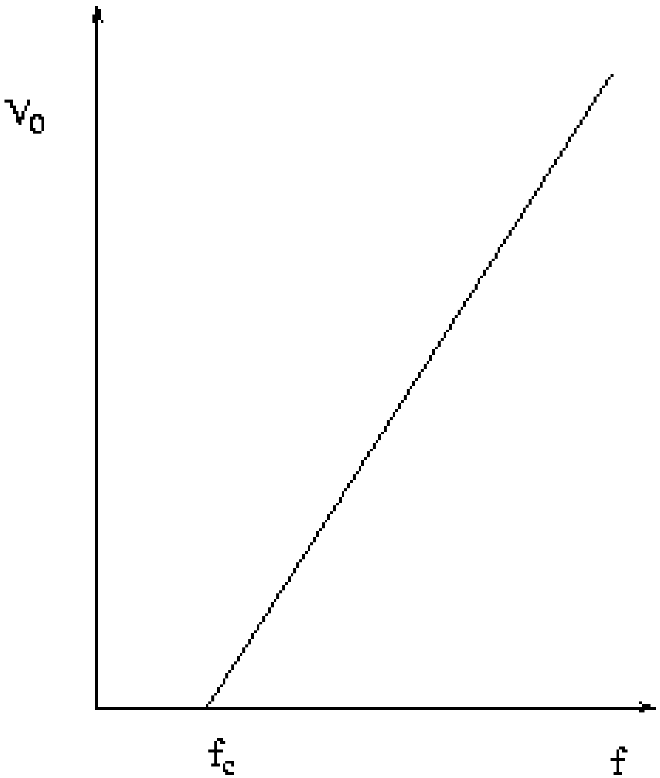
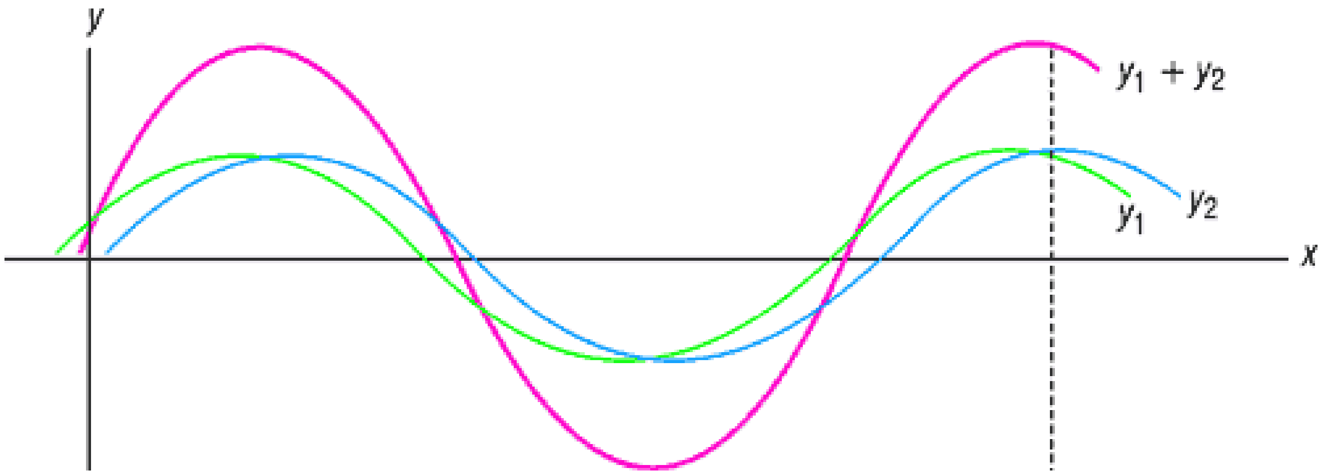
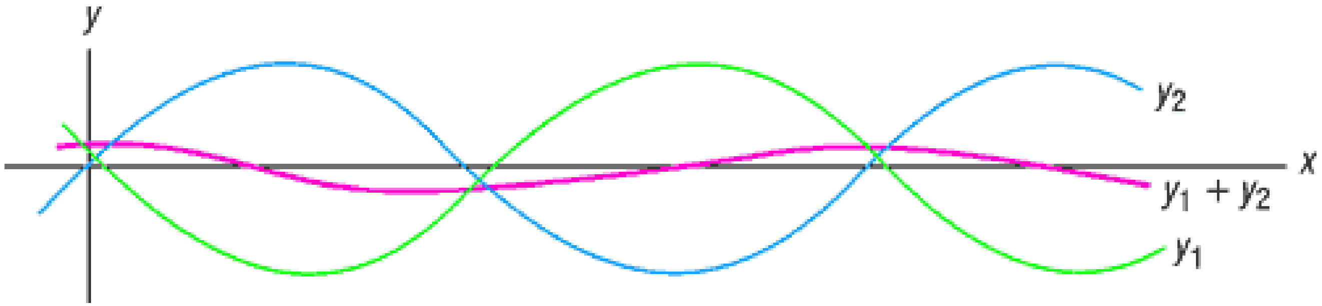




$$E_{e-} = hc/\lambda - W_0$$

Where W_0 = characteristic escape energy for the metal
E_{e-} = the kinetic energy of an escaping electron
hc/λ = the energy of the photon of wavelength λ





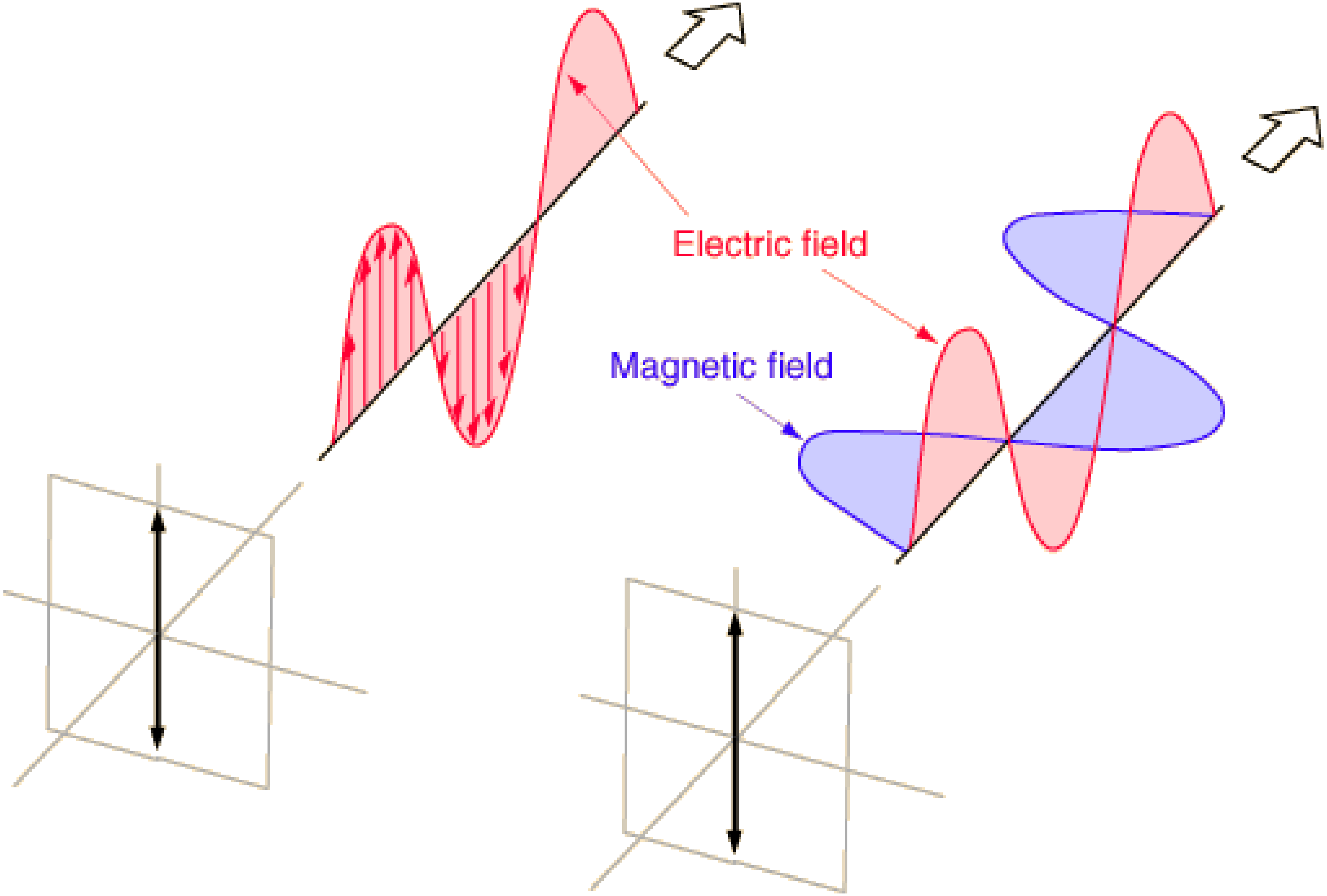
SUPERPOSITION (INTERFERENCE)

When can we ignore polarization?

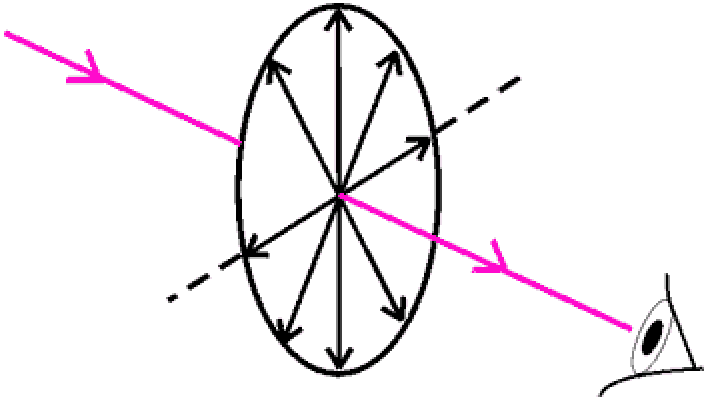
- Imaging problems
- Interference/diffraction for beams at
- small angles

When is it important?

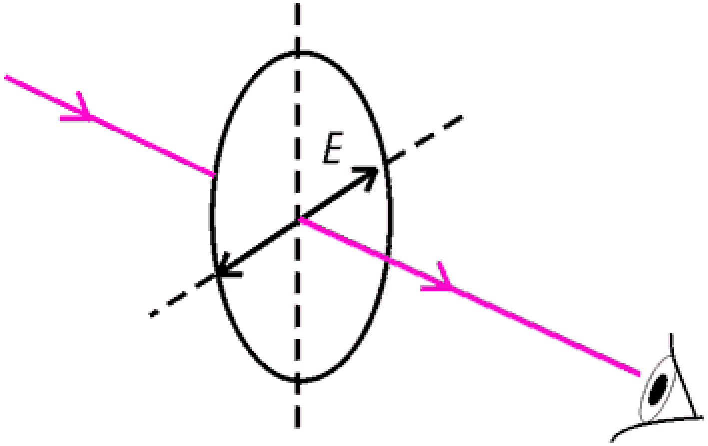
- Transmittance/reflectance calcs
- Superposing beams at large angles
- Detailed interactions with matter:
  - Birefringent materials, surface effects,
  - atomic/molecular transitions, nonlinear optics, magneto-optical effects, electro-optical effects, . . .



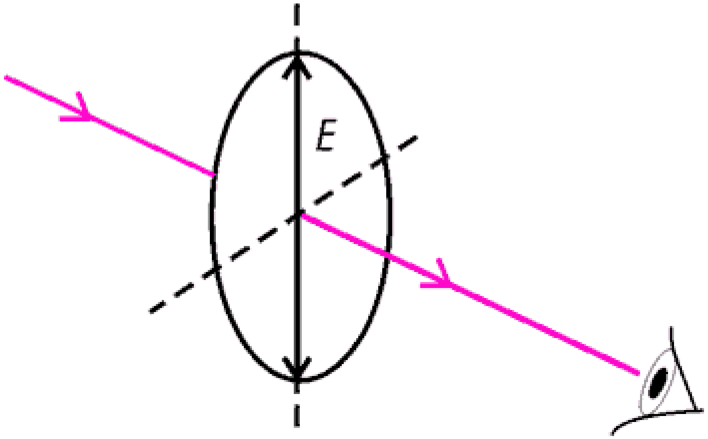
PLANE POLORIZED



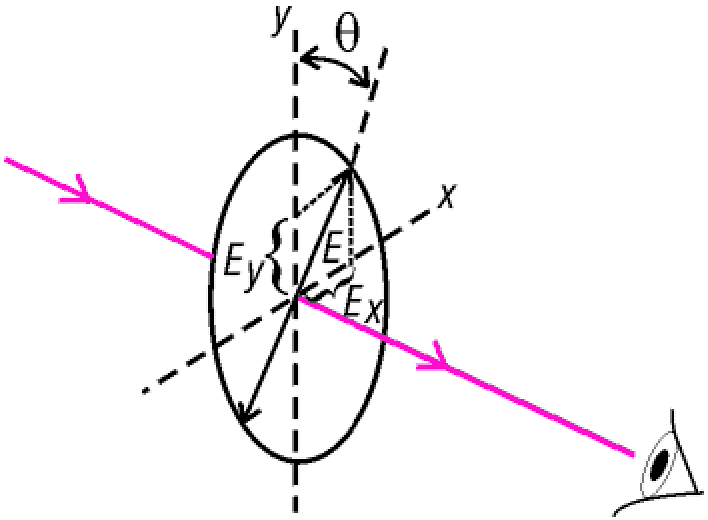
UNPOLARIZED



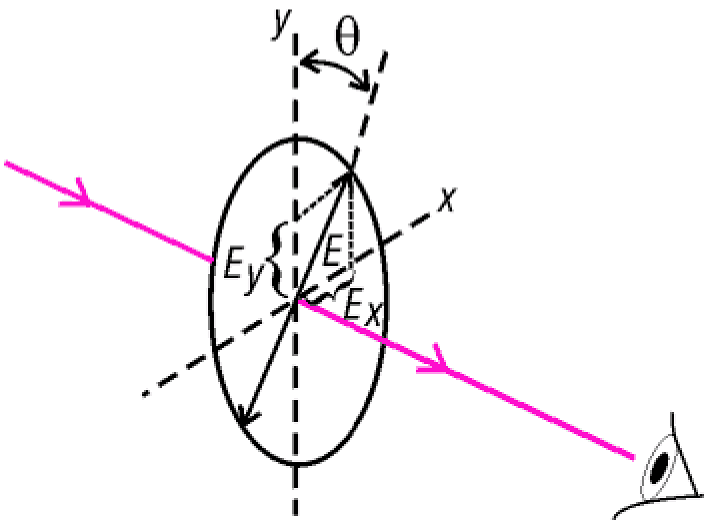
HORIZONTALLY POLARIZED



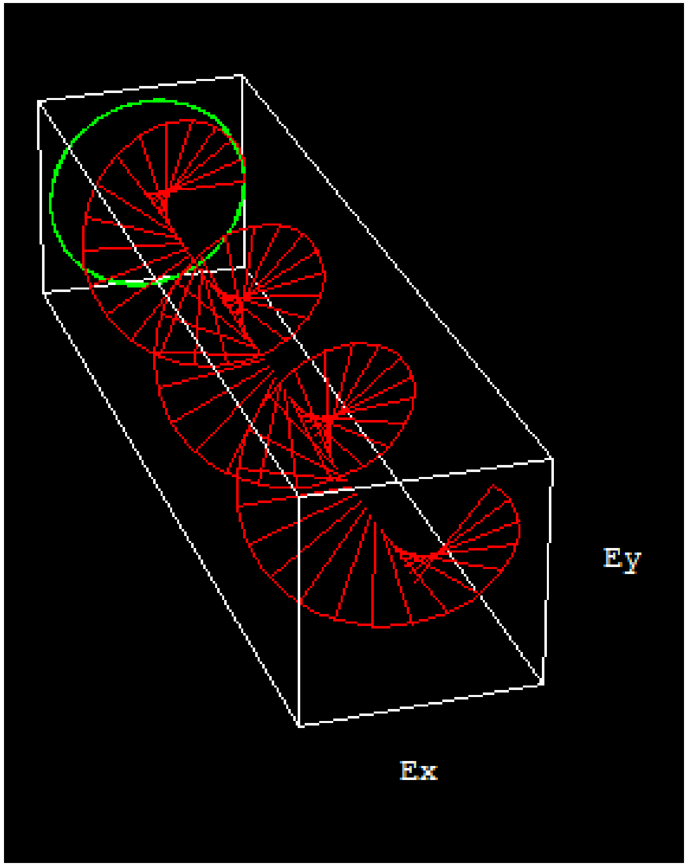
VERTICALLY POLARIZED

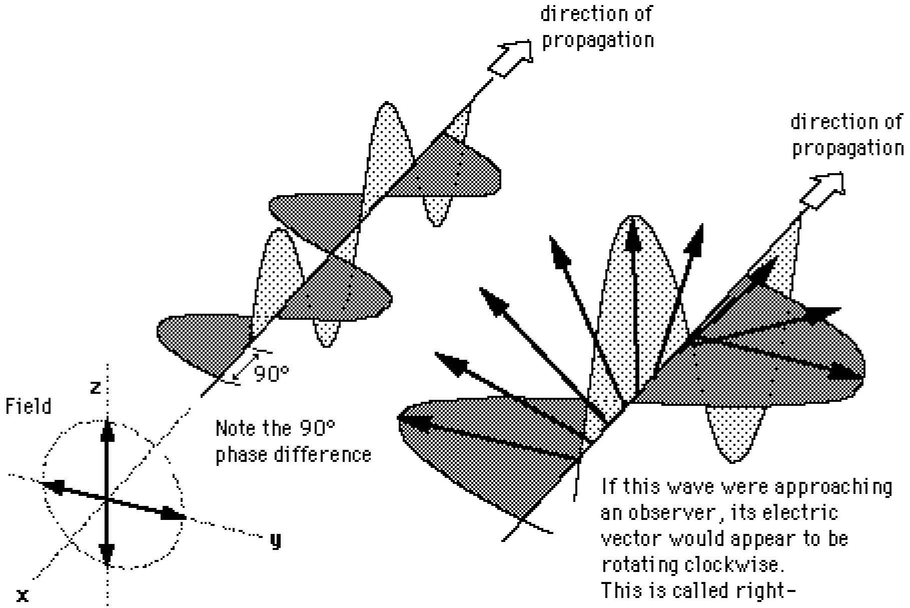


PLANE POLARIZED
GENERAL CASE



y= vibration direction of light (direction of E vector)


Ey
Ex



Note the 90° phase difference

If this wave were approaching an observer, its electric vector would appear to be rotating clockwise.
This is called right-circular polarization.

The electric field is made up of an x-component and a y-component.

If the x and y-components are equal in magnitude and differ in phase by 90-degrees circular polarization will result. The figures below show a representation of the resulting polarization.

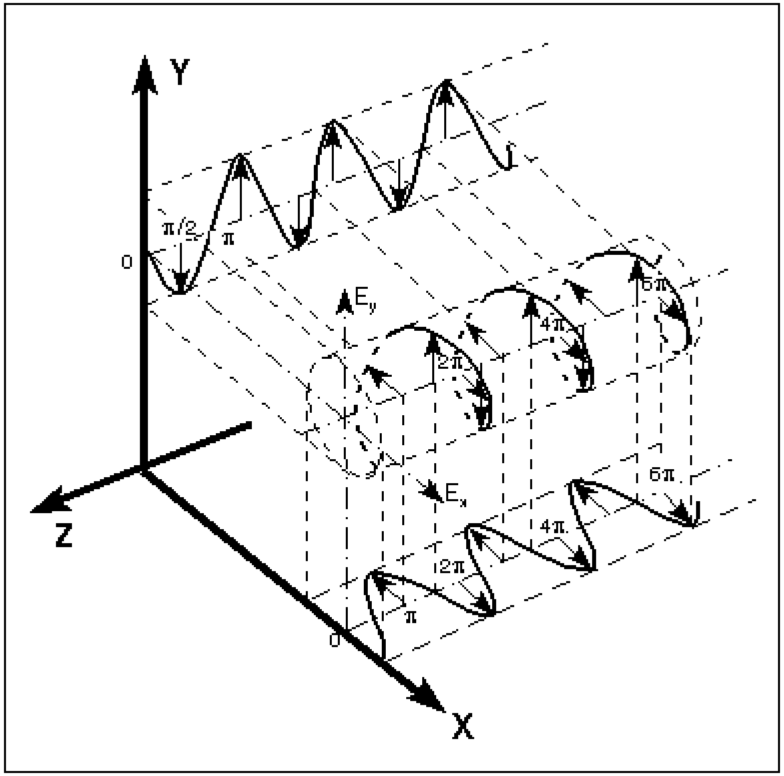
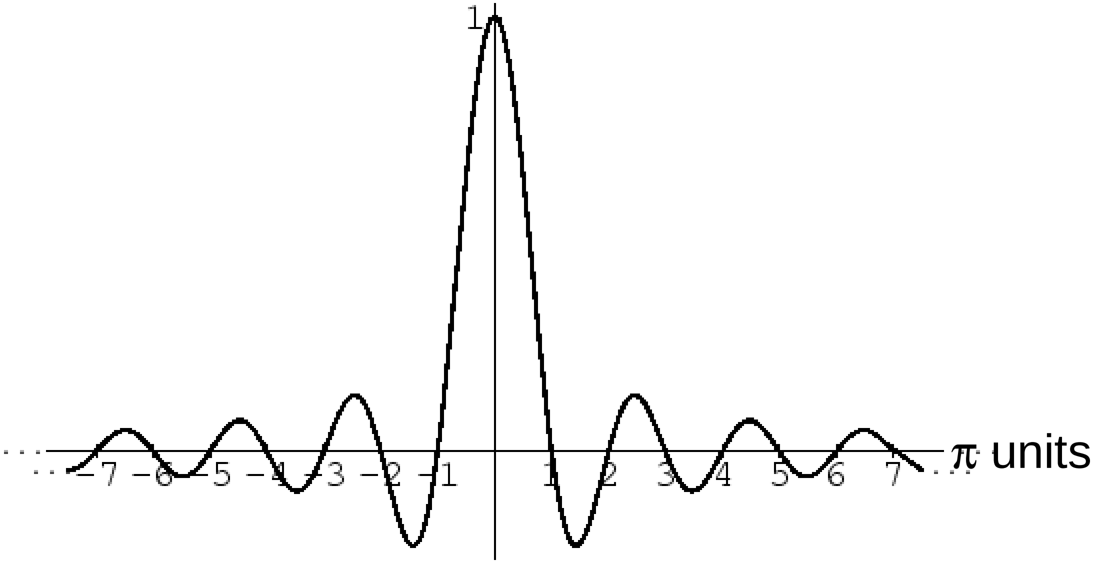


Figure 3. CIRCULAR POLARIZATION - E FIELD

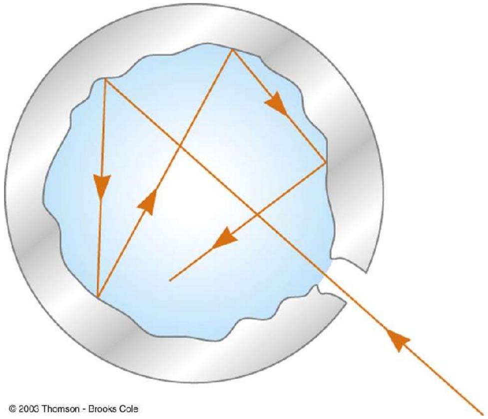
Sinc function



- Max Planck (1900)
  - first major result of quantum mechanics
  - Planck curves describe variation of energy flux as a function of temperature and wavelength
- Wien’s law
  - describes wavelength of peak energy flux
- Stefan-Boltzmann law
  - describes total energy output

Blackbody

- Above absolute zero (= -273.15 C = 0 K) all objects radiate at all wavelengths
- Blackbody is an idealized system that absorbs incident radiation of all wavelengths
- A blackbody is an ideal emitter; it absorbs energy completely at all wavelengths and emits a radiation field that is proportional to its temperature. Cavity is a good real-life approximation to a blackbody



- A blackbody
  - is a perfect emitter of electromagnetic radiation at all wavelengths
    - no ‘stored’ energy
  - is a perfect absorber of electromagnetic radiation
    - no reflection of incident radiation

Planck Law

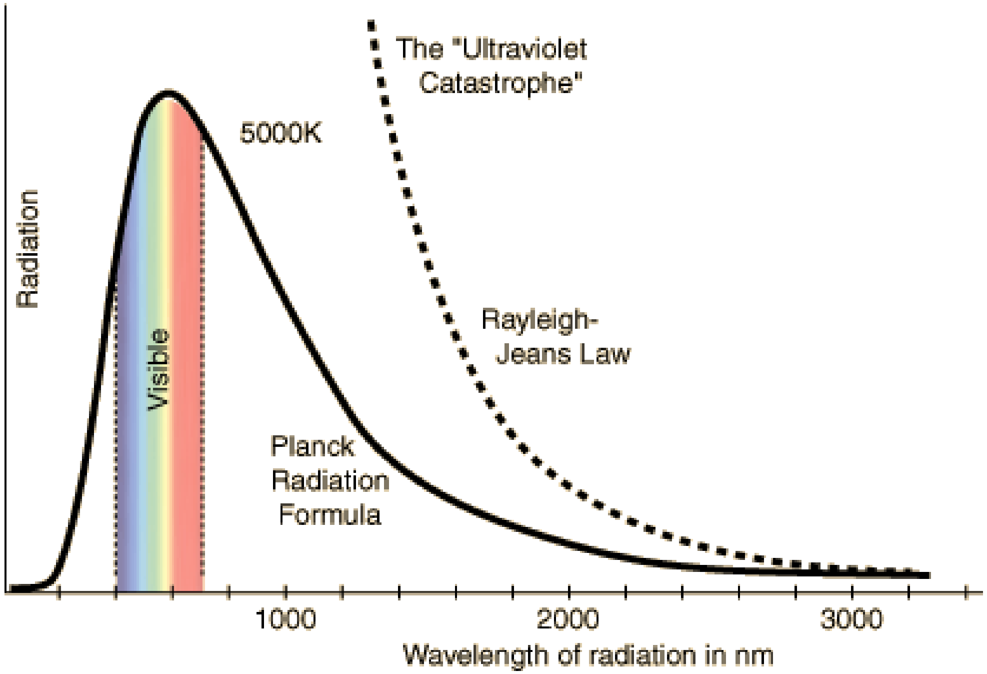
$$\frac{8\pi\nu^2}{c^3}\,\frac{h\nu}{e^{\frac{h\nu}{kT}}-1}$$

Quantum

Classical

Rayleigh-Jeans Law

$$\frac{8\pi\nu^2}{c^3}\,kT$$



$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots$$

$$e^{\frac{h\nu}{kT}} = 1 + \frac{h\nu}{kT} + \frac{\left[\frac{h\nu}{kT}\right]^2}{2!} + \frac{\left[\frac{h\nu}{kT}\right]^3}{3!} + \ldots$$

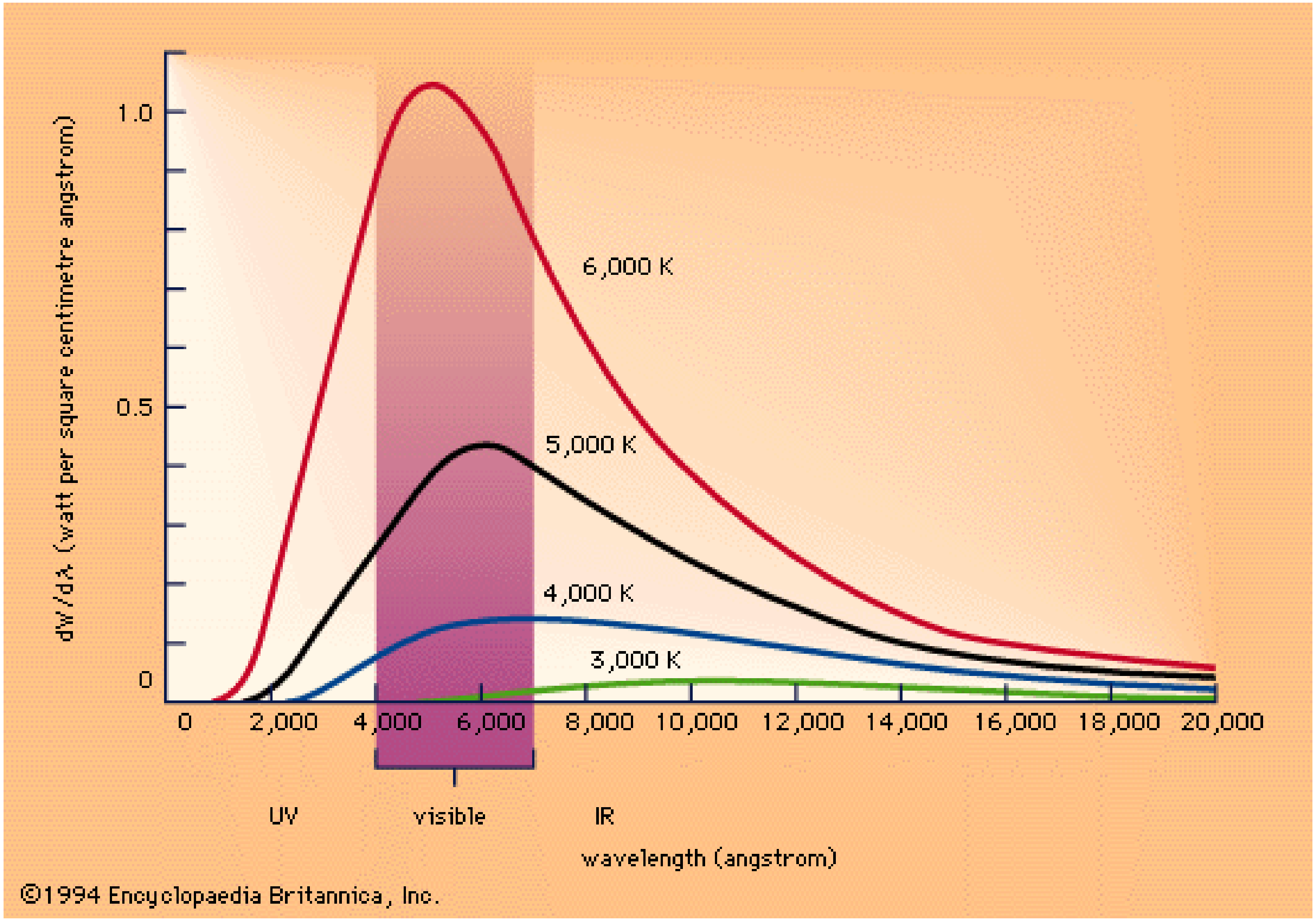
$$\approx 1 + \frac{h\nu}{kT}$$ for $h\nu \ll kT$

Low frequencies

For low frequencies the Planck Law agrees with the classical Rayleigh-Jeans Law

$$\frac{8\pi\nu^2}{c^3}\,\frac{h\nu}{1+\frac{h\nu}{kT}-1} = \frac{8\pi\nu^2}{c^3}\,kT$$

Planck Curve and Blackbody (Thermal) Radiation



- A key result:

A BB at temperature T_1 will emit more energy, at all wavelengths, than a BB at temperature T_2 provided, $T_2 < T_1$

The ‘shape’ of the BB curve is described by the Planck Function

$$I(\quad ,T)=\left(\frac{2\pi h c^2}{\quad 5}\right)\left(\frac{1}{\exp(hc/\quad kT)-1}\right)$$

A backbody radiates proportional to its temperature. Spectral radiance, I(,T), is determined by **Planck's Radiation Law**:

$$I(\quad ,T)=\left(\frac{2\pi\ h\ c^{2}}{\quad ^{5}}\right)\left(\frac{1}{\exp(hc/\quad kT)-1}\right)$$

h = Planck's constant = 6.6260755 = 10^{-34} joule-second

k = Boltzmann's constant = 1.3807 x 10^{-23} joule-kevins

Blackbody Radiators

- Most hot objects can be approximated (to some degree) as blackbody radiators - stars certainly can

- BB theory describes amount of electromagnetic energy radiated as a function of wavelength

- BB's have well defined characteristics
  - all described by their temperature T

Planck’s law defines the nature of blackbody radiation. Real objects are not blackbodies so a correction for **emissivity** should be made.

$$\text{Emissivity} = \frac{\text{Radiant energy of an object}}{\text{Radiant energy of a black body with the same temperature as the object}}$$

Emissivity ranges between 0 and 1 depending on the dielectric constant of the object, surface roughness, temperature, wavelength, look angle.
The temperature of the black body which radiates the same radiant energy as an observed object is called the **brightness temperature** of the object.

Many natural surface materials are well approximated by blackbodies in the infrared region. For instance, water has a thermal infrared emissivity of .98.

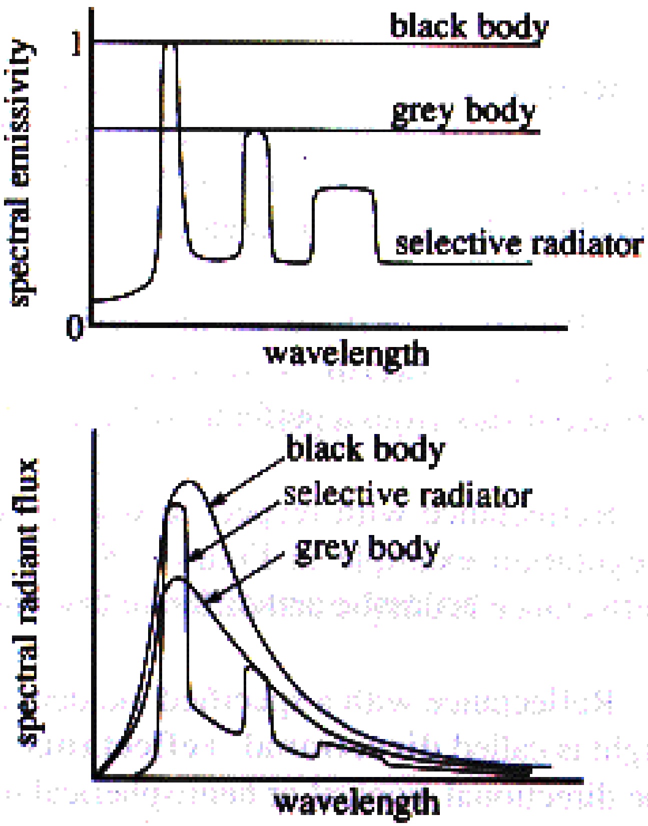
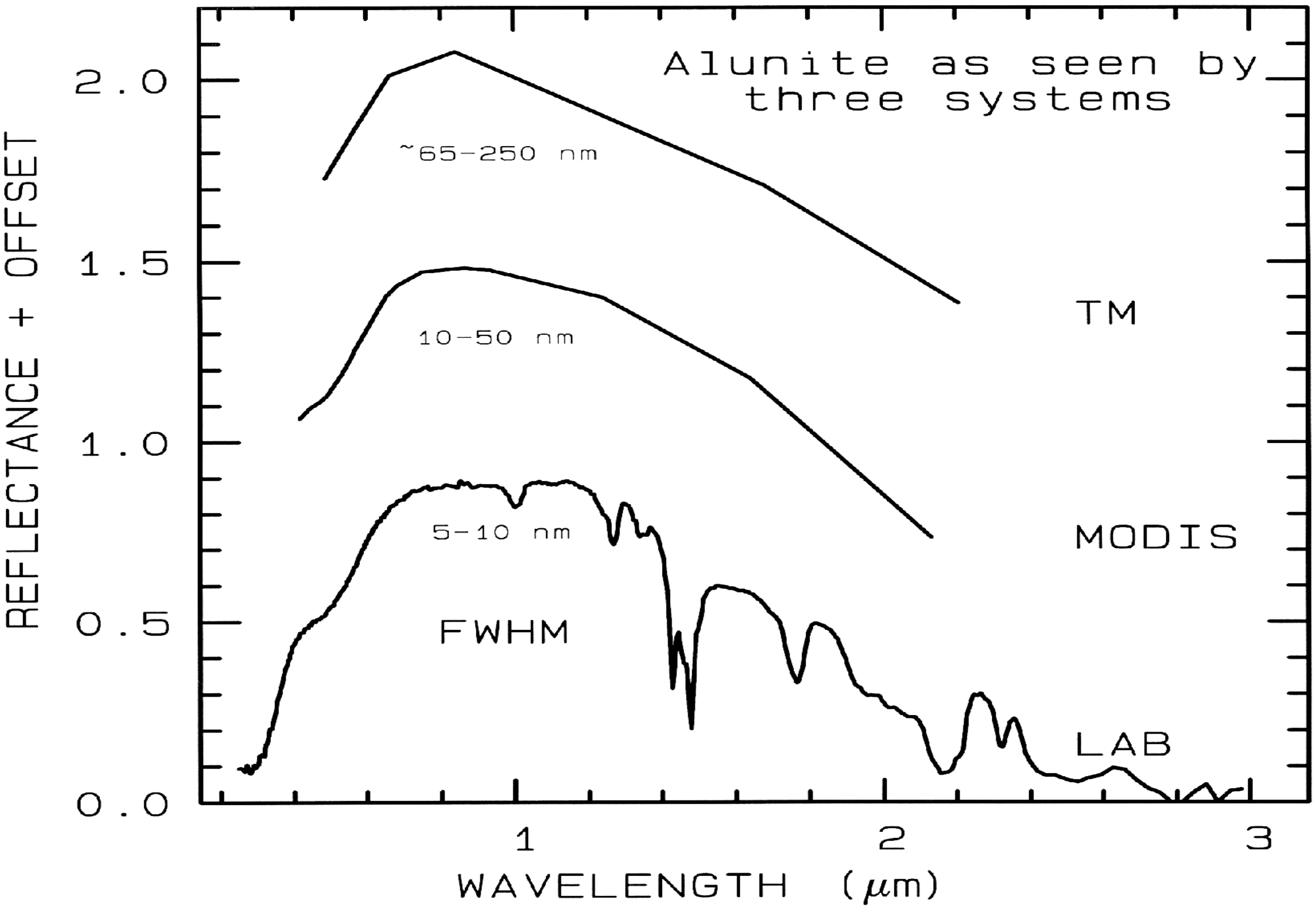


Figure 1.7.2 Radiators

The spectral emissivity and spectral radiant flux for three objects that are a black body, **a gray body** and a selective radiator.

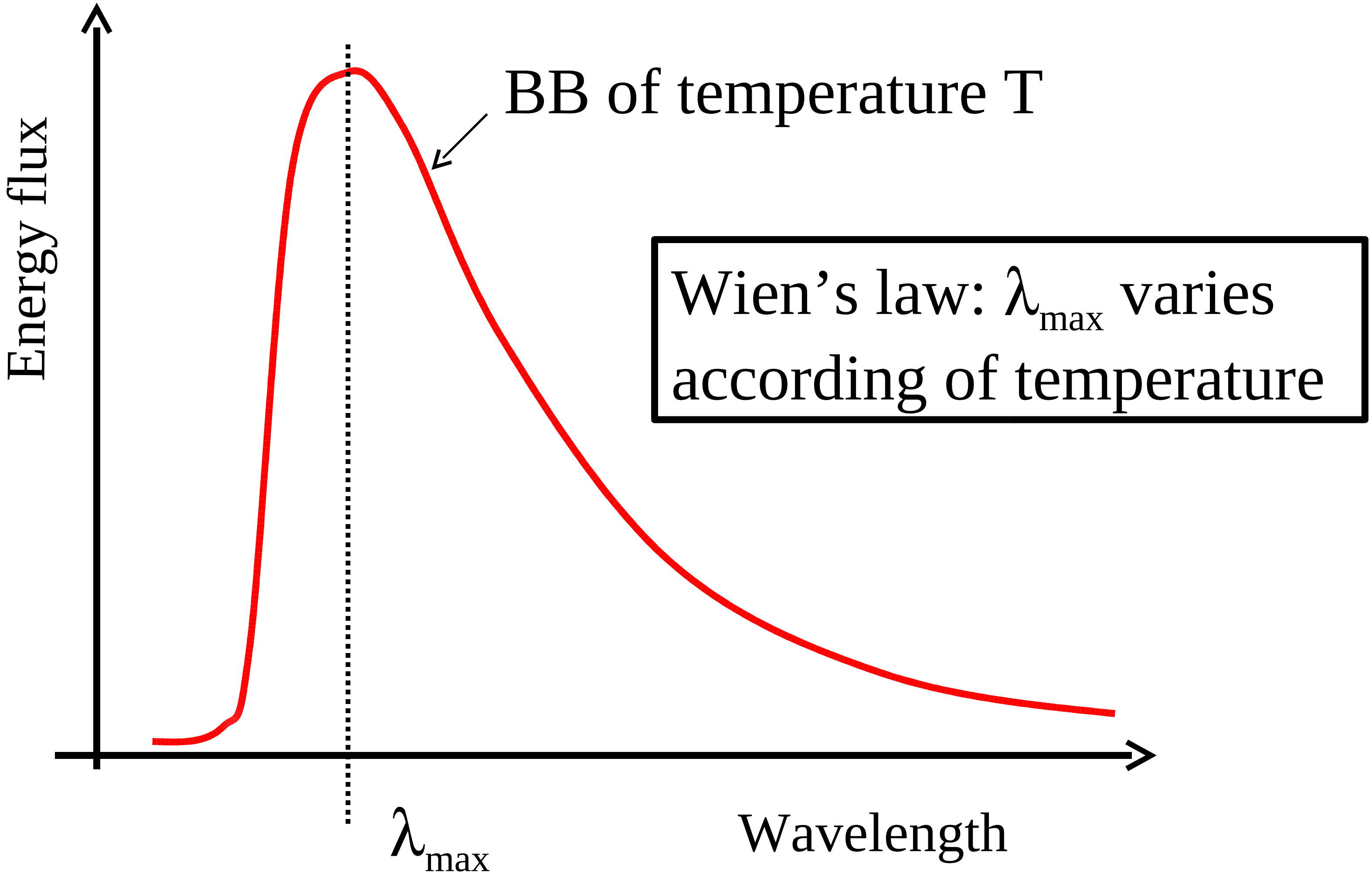

Alunite as seen by three systems
~65-250 nm
10-50 nm
5-10 nm
FWHM
TM
MODIS
LAB
REFLECTANCE + OFFSET
2.0
1.5
1.0
0.5
0.0
1
2
3
WAVELENGTH (μm)

Wien's Law

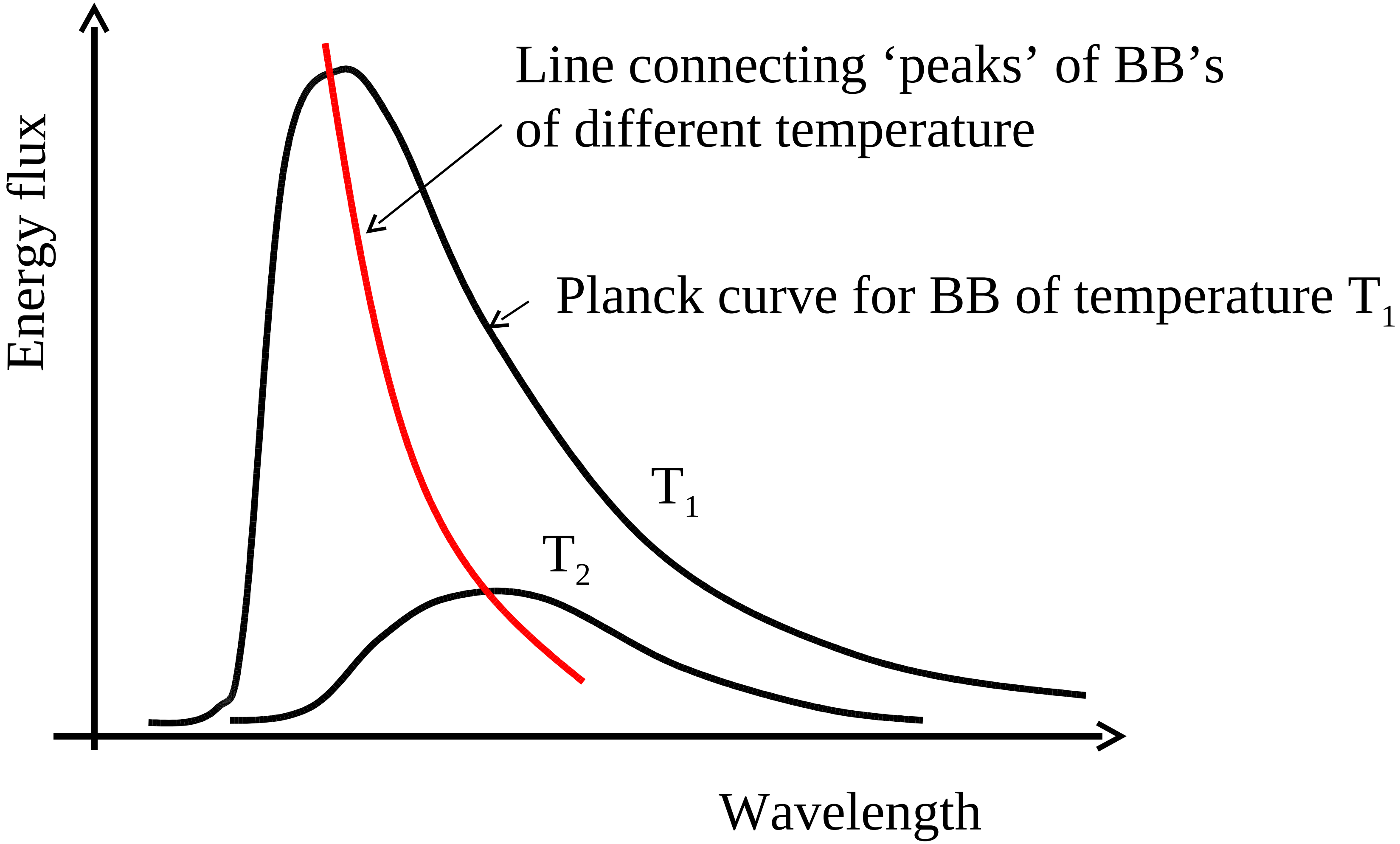
- The wavelength (λ_{max}) at which a BB emits the maximum amount of energy decreases with increasing temperature

$$\boxed{\lambda_{max} T = 2.8977 \times 10^{-3}}$$

- units: λ in meters, T in Kelvin



Wien's law: λ_{max} varies according of temperature

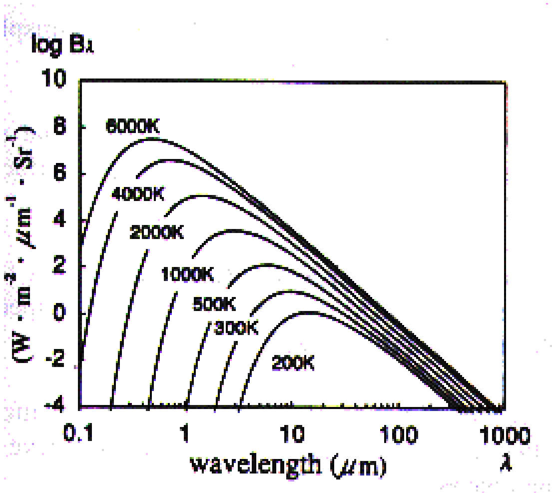


Line connecting ‘peaks’ of BB’s of different temperature

Planck curve for BB of temperature T_1

Wien’s Displacement Law:

$$\lambda_{max} = \frac{k}{T}$$



k = 2898 μm K, and T is the absolute temperature in degrees Kelvin

It is obtained by differentiating the spectral radiance.

It shows that the product of wavelength (corresponding to the maximum peak of spectral radiance) and temperature, is approximately 3,000 (μmK is the best for measurement of objects with a temperature of 300K.

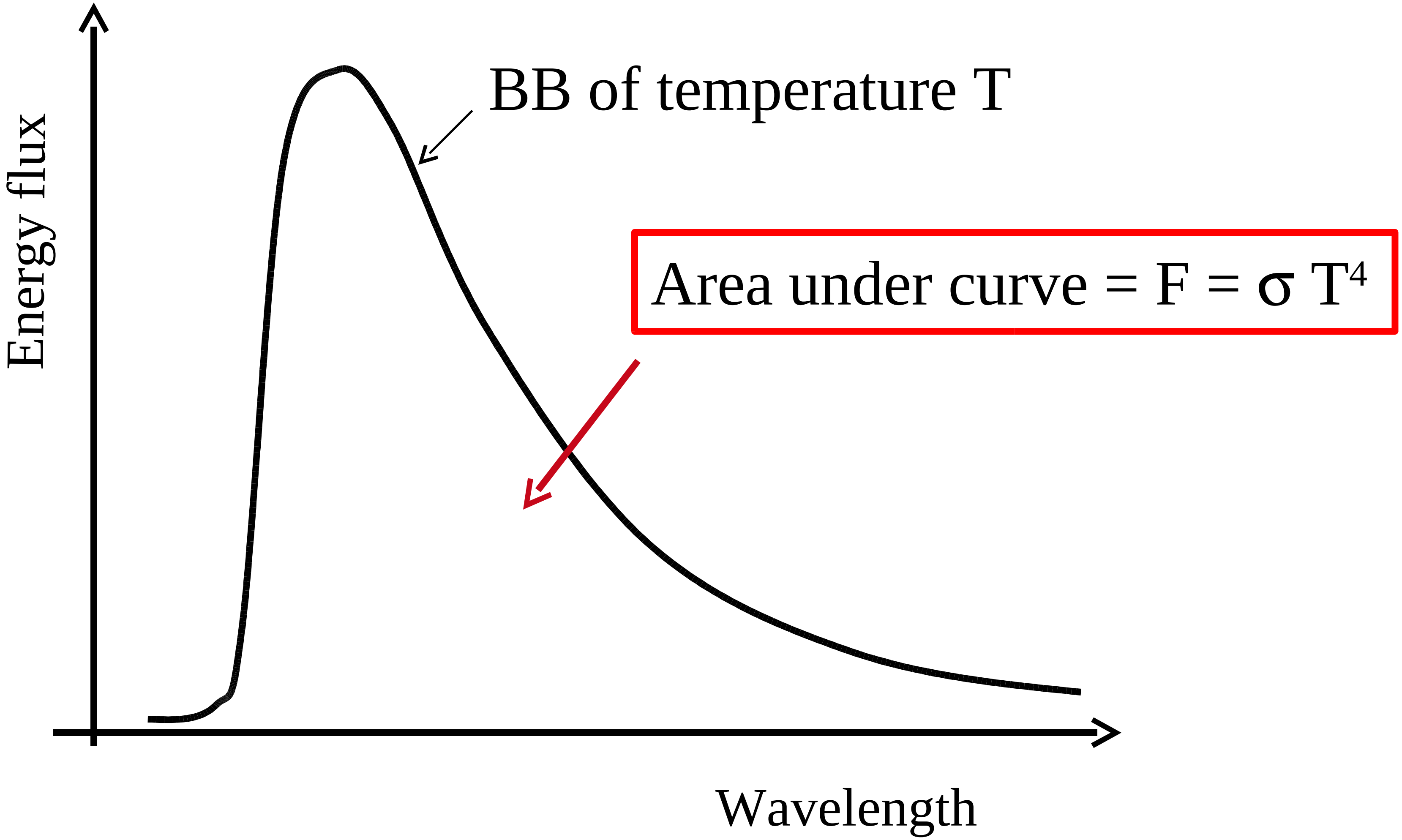
This law is useful for determining the optimum (peak) wavelength for temperature measurement of objects with a temperature of T. For example, about 10μm is the best for measurement of objects with a temperature of 300K.

The Stefan - Boltzmann law

- The energy emitted per second per m^2 (the energy flux F) increases with temperature:

$$\boxed{F = \sigma T^4}$$

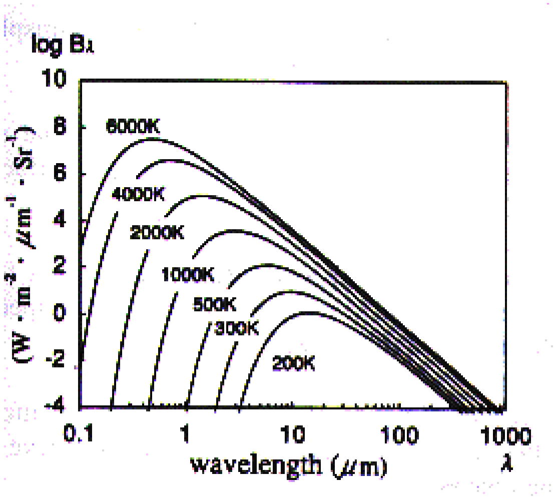
- Units: Flux in Watts/m^2, T in Kelvin
- Stefan-Boltzmann constant (σ) = 5.67×10^{-8}



Area under curve = F = σT^4

Stefan-Boltzmann Law:

$$M_\lambda = \sigma T^4$$



Where σ is the Stefan-Boltzmann constant, 5.6697 x 10^{-8} $W^{-2}K^{-4}$

Gives the total amount of emitted radiation from a blackbody

Units: (Same as radiant emittance) W m^{-2}

Proportional to T^4

Obtained by integrating the area under the Planck Curve.