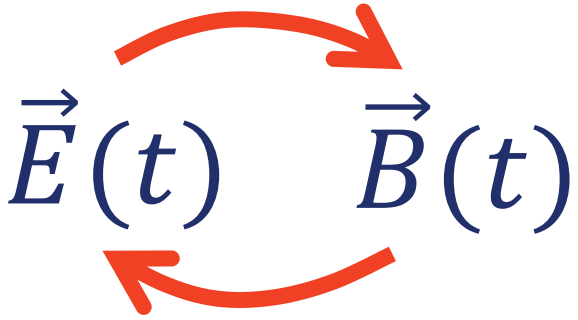
elektromagnetická vlna

elektromagnetické vlny

$$\oint_{\partial S} \vec{E} \cdot \mathrm{d}\vec{s} = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_S \vec{B} \cdot \mathrm{d}\vec{S}$$

$$\oint_{\partial S} \vec{B} \cdot \mathrm{d}\vec{s} = \mu_0 I + \mu_0 \varepsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_S \vec{E} \cdot \mathrm{d}\vec{S}$$



Stokesova věta, $I = 0, \rho = 0,$

$$\operatorname{rot} \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\operatorname{rot} \vec{B} = \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$\operatorname{div} \vec{E} = 0$$

$$\operatorname{div} \vec{B} = 0$$

$$\nabla^2 \vec{E} = \frac{\partial^2 \vec{E}}{\partial x^2} + \frac{\partial^2 \vec{E}}{\partial y^2} + \frac{\partial^2 \vec{E}}{\partial z^2} = \Delta \vec{E} = \frac{1}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2}$$

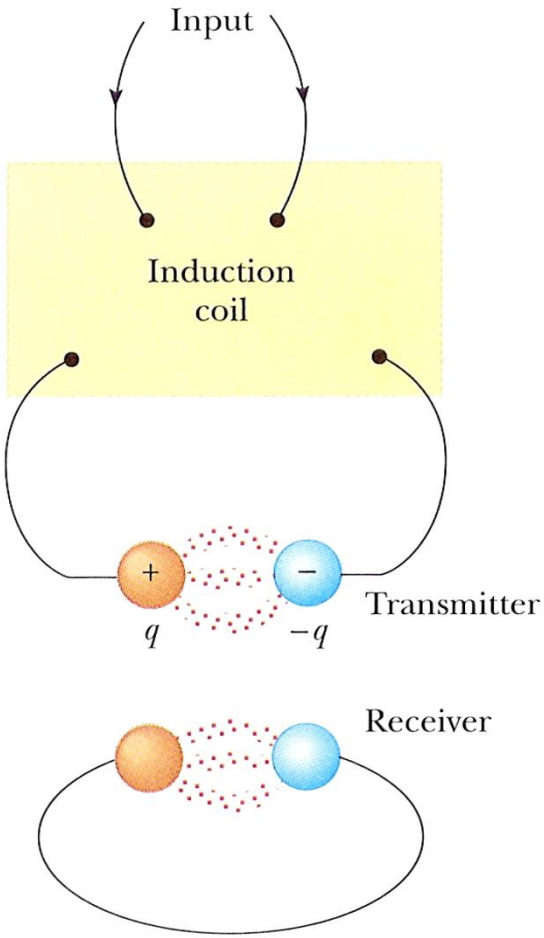
$$\nabla^2 \vec{B} = \frac{\partial^2 \vec{B}}{\partial x^2} + \frac{\partial^2 \vec{B}}{\partial y^2} + \frac{\partial^2 B}{\partial z^2} = \Delta \vec{B} = \frac{1}{c^2} \frac{\partial^2 \vec{B}}{\partial t^2}$$

$$\left(\operatorname{rot} \operatorname{rot} = \operatorname{grad} \operatorname{div} - \nabla^2 \right)$$

$$\mu_0 \varepsilon_0 = c^{-2}$$

vlnové rovnice
(platí pro souřadnice)

experimentální důkaz



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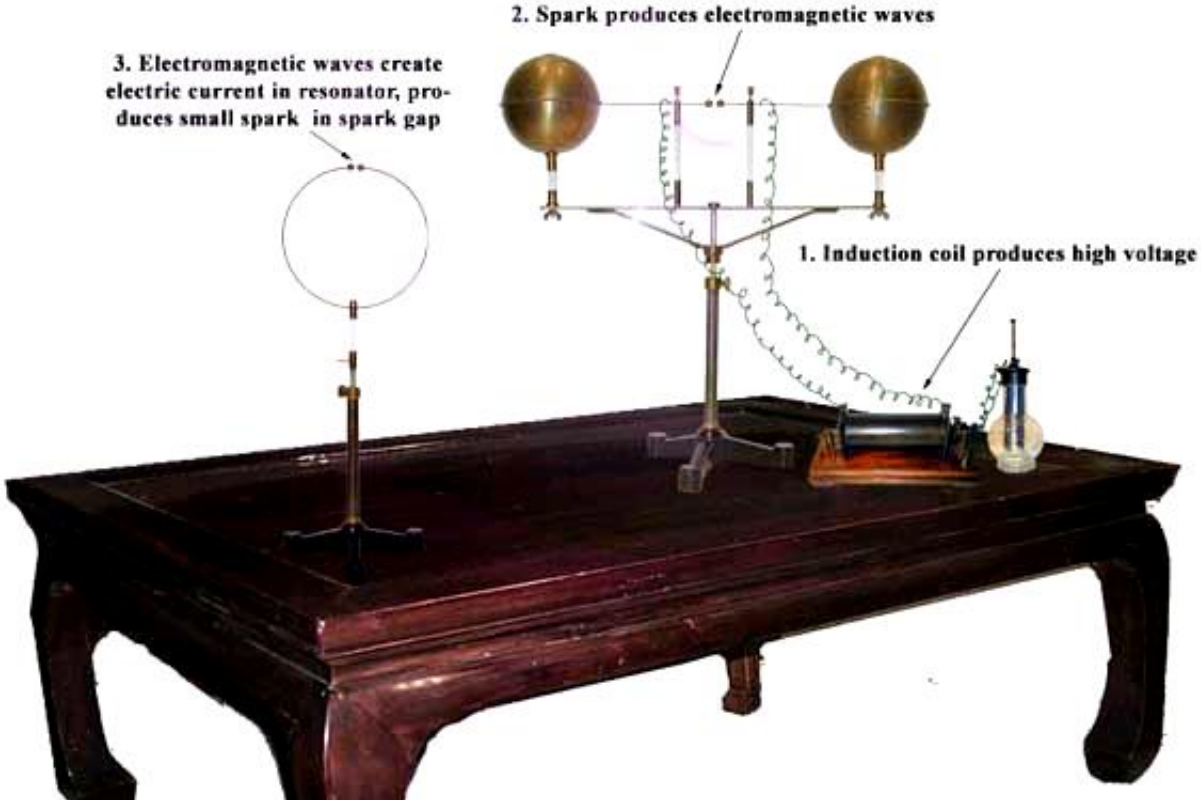


rovinná elektromagnetická vlna

$$\Delta\vec{E} = \frac{1}{c^2}\frac{\partial^2\vec{E}}{\partial t^2} \qquad \Delta\vec{B} = \frac{1}{c^2}\frac{\partial^2\vec{B}}{\partial t^2}$$

existuje řešení:

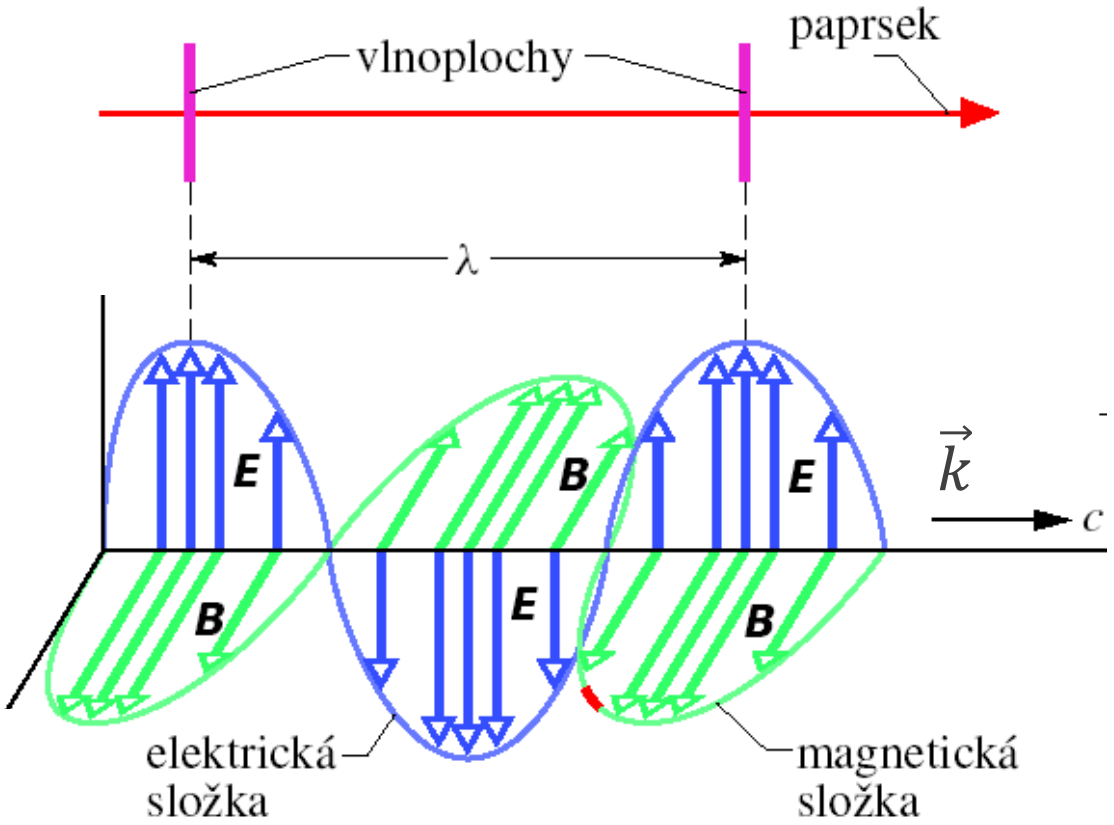
$$\vec{E} = \vec{E}_0 \sin\left(\vec{k}\cdot\vec{r} - \omega t\right)$$
$$\vec{B} = \vec{B}_0 \sin\left(\vec{k}\cdot\vec{r} - \omega t\right)$$

kde:

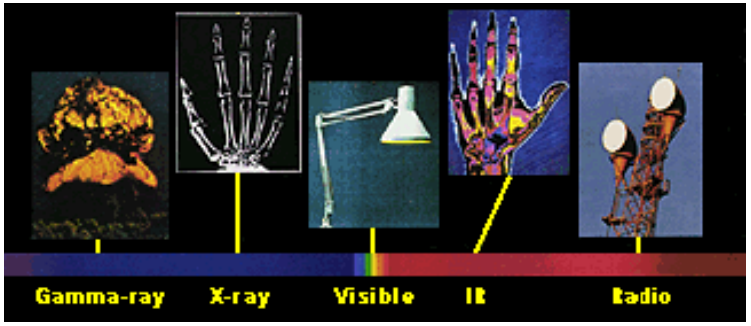
$$k = \frac{\omega}{c} = \frac{2\pi}{\lambda}$$

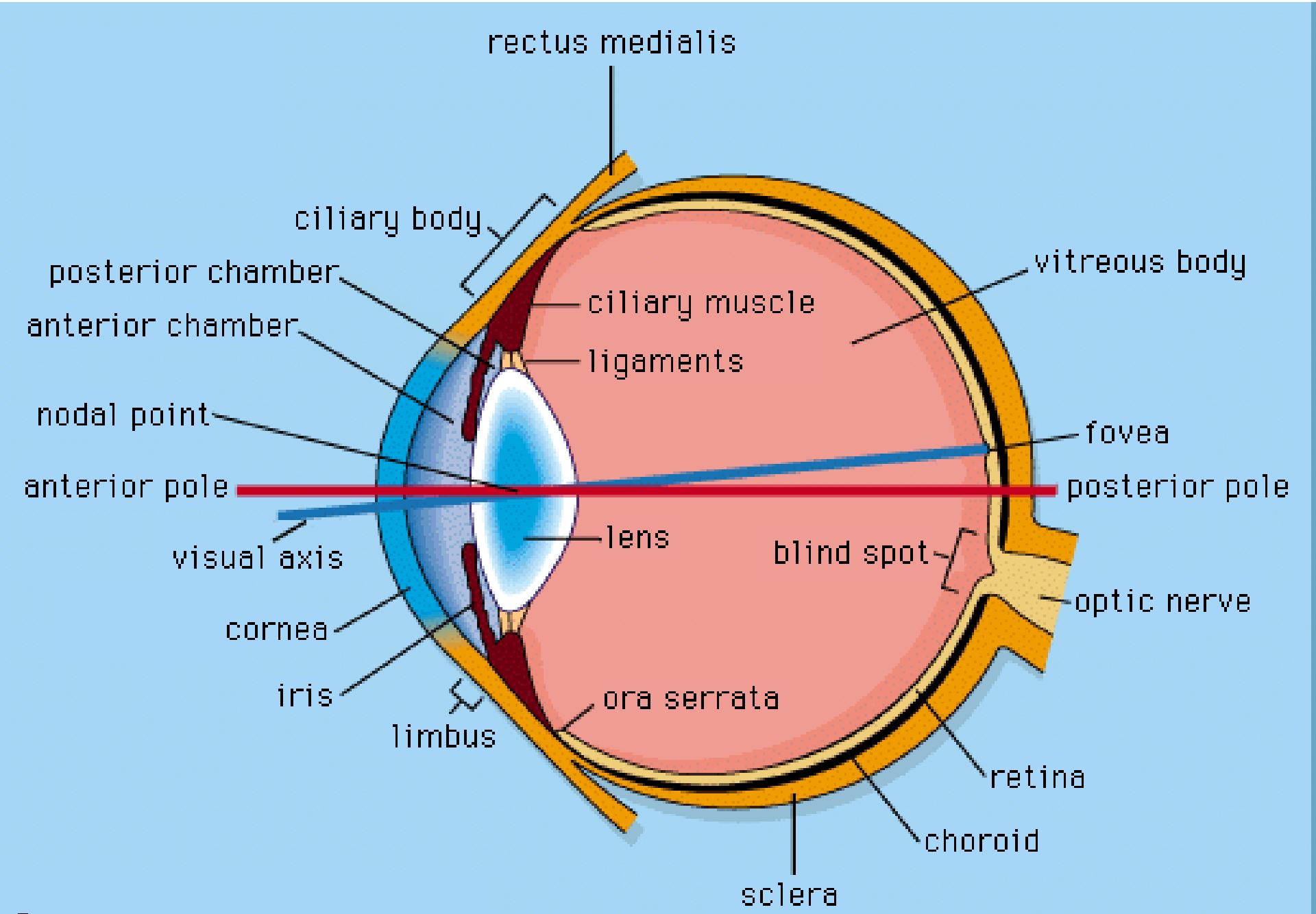
dosazením řešení do Maxwellových rovnic:

$$\vec{E} \perp \vec{B} \perp \vec{k}$$
$$E = cB$$

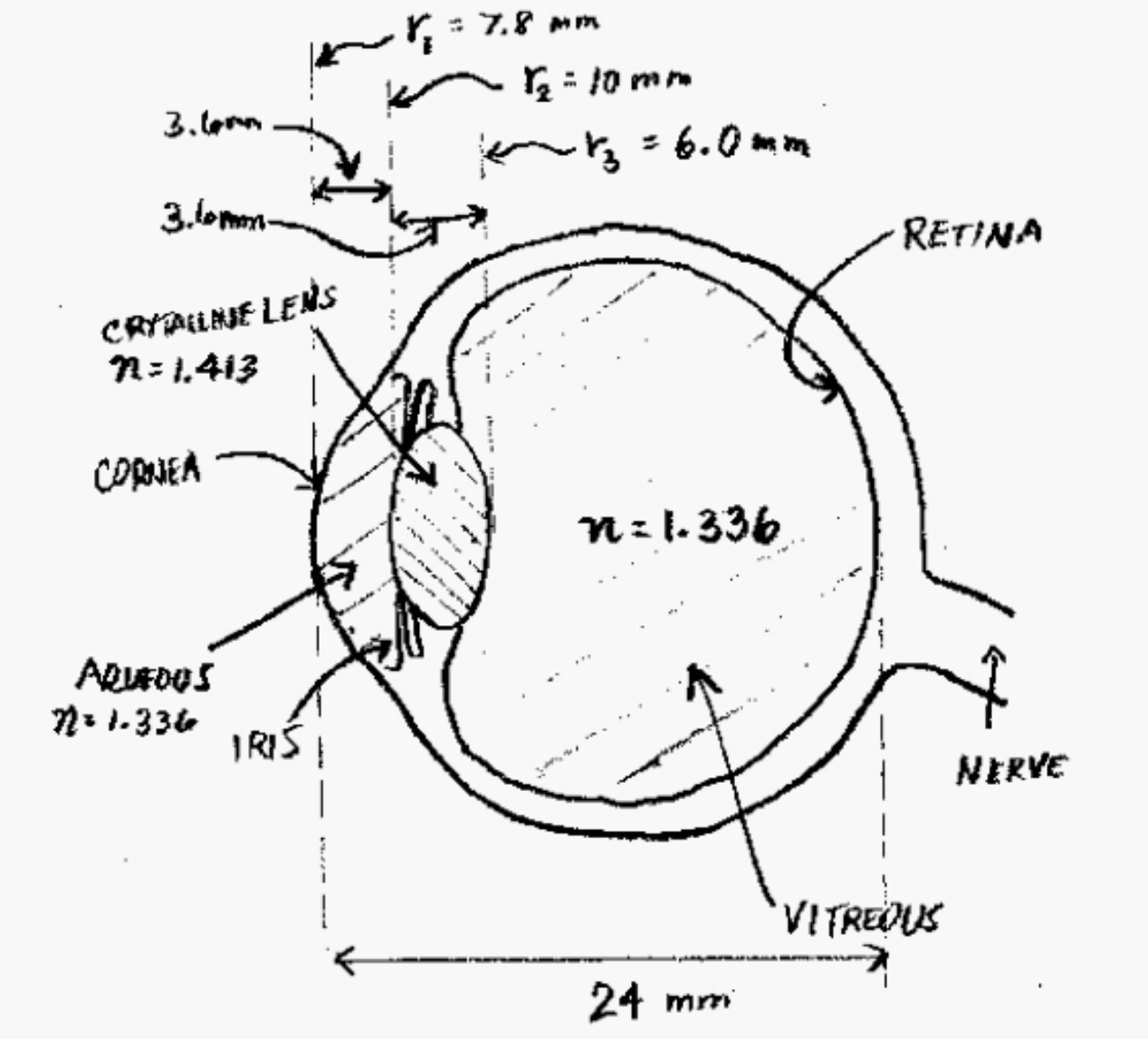


Maxwellova duha





Gullstrandův model oka



viditelná část spektra

Approximate wavelength (in vacuum) and frequency ranges for the various colours

Colour	**Wavelength** (nm)	**Frequency** (THz, 10^{12} Hz)
Red	**780 - 622**	**384 - 482**
Orange	**622 - 597**	**482 – 503**
Yellow	**597 - 577**	**503 - 520**
Green	**577 - 492**	**520 - 610**
Blue	**492 - 455**	**610 - 659**
Violet	**455 - 390**	**659 - 769**

Poyntingův vektor

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

… **tok energie** (energie procházející jednotkovou plochou kolmou k vektoru $\vec{S}$ za jednotku času)

$$\operatorname{div}\left(\frac{1}{\mu_0}\vec{E} \times \vec{B}\right) = \frac{1}{\mu_0}\left(\vec{B} \cdot \operatorname{rot}\vec{E} - \vec{E} \cdot \operatorname{rot}\vec{B}\right) =$$

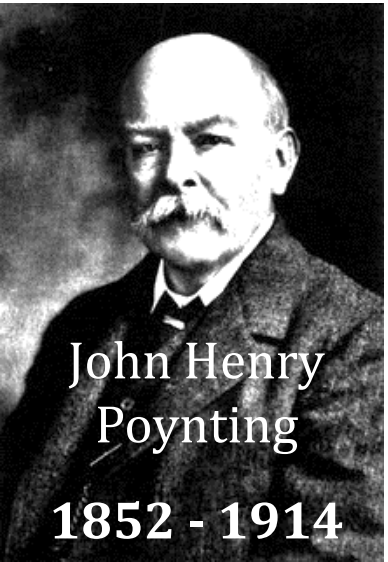
$$= \frac{1}{\mu_0}\left[\vec{B} \cdot \left(-\frac{\partial \vec{B}}{\partial t}\right) - \vec{E} \cdot \left(\mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}\right)\right] = -\frac{\partial}{\partial t}\left(\frac{B^2}{2\mu_0} + \frac{\varepsilon_0 E^2}{2}\right) = -\frac{\partial}{\partial t}(w_m + w_e)$$

hustota energie:

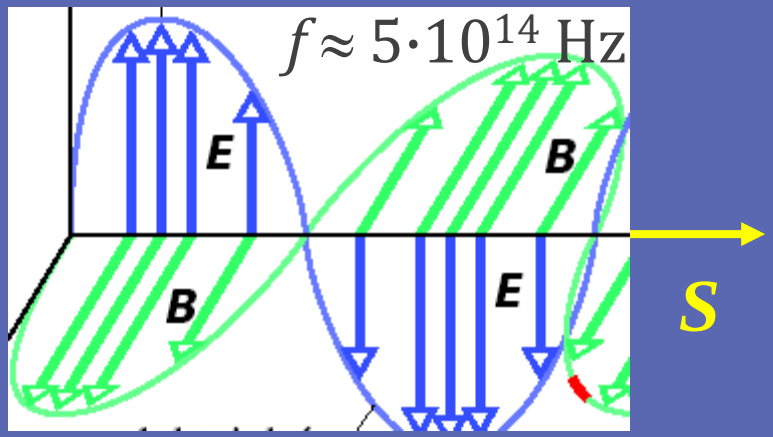
$$w = w_m + w_e = \frac{\varepsilon_0 E^2}{2} + \frac{\varepsilon_0 E^2}{2} = \frac{EB}{c\mu_0} \quad (\mathrm{J \cdot m^{-3}})$$

rovinná vlna: $(E = cB, \mu_0\varepsilon_0 = c^{-2})$

$$\vec{S} = S\frac{\vec{k}}{k} = \frac{EB}{\mu_0}\frac{\vec{k}}{k} = cw\frac{\vec{k}}{k} \quad (\mathrm{J \cdot m^{-3} \cdot s^{-1}} = W \cdot \mathrm{m^{-2}})$$



intenzita záření (světla)



$$I = \langle S \rangle = \frac{1}{c\mu_0} \langle E^2 \rangle = \frac{1}{c\mu_0} E_{\text{ef}}^2$$

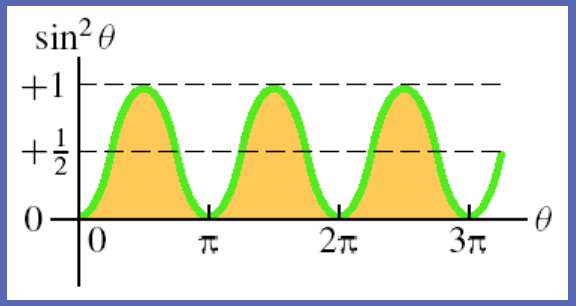
$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}$$

E/c

$$\langle S \rangle = \frac{1}{\mu_0} \langle EB \rangle = \frac{1}{c\mu_0} \langle E^2 \rangle$$

$$E = E_{\text{m}} \sin(kx - \omega t)$$

$$\langle E^2 \rangle = \frac{1}{T} \int_0^T E_{\text{m}}^2 \sin^2(kx - \omega t)\, \mathrm{d}t = \frac{E_{\text{m}}^2}{2} = E_{\text{ef}}^2$$



hybnost elektromagnetického pole a tlak záření

hustota hybnosti

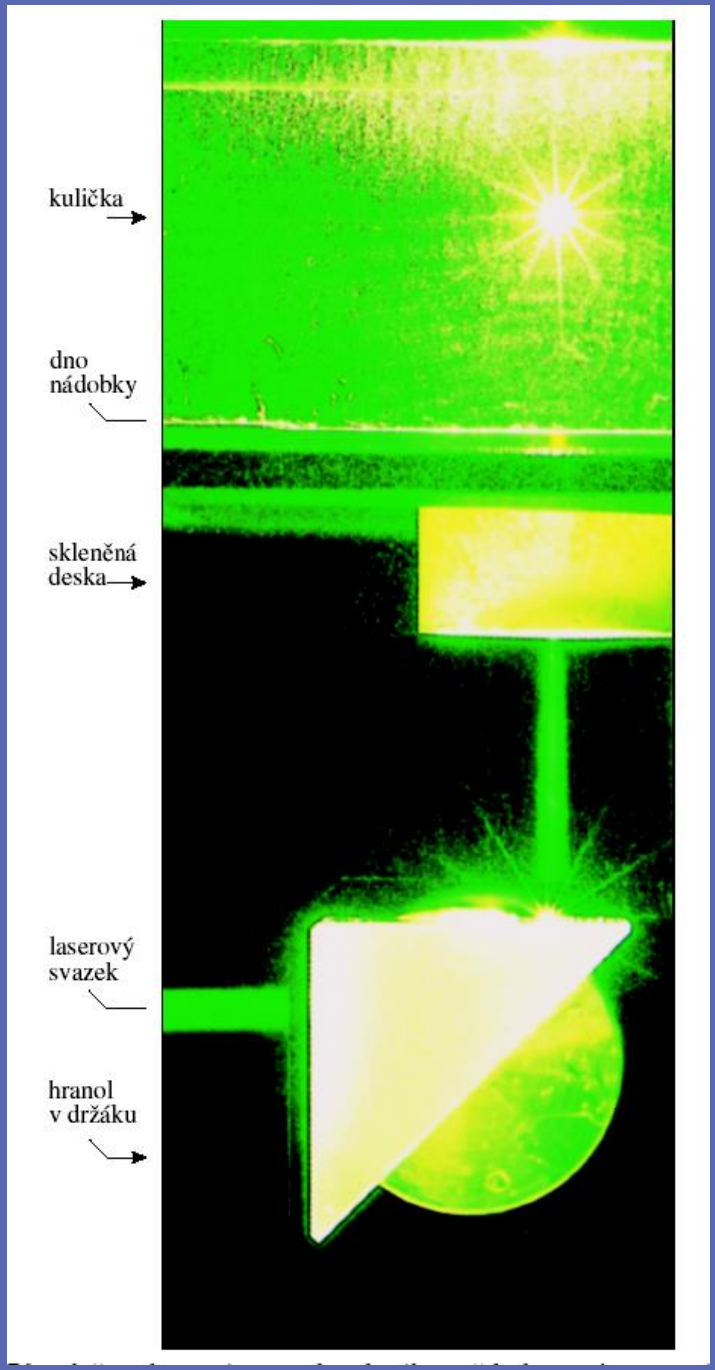
$$\pi = \rho c = w/c$$

w/c^2

tlak záření při absorpci odrazu

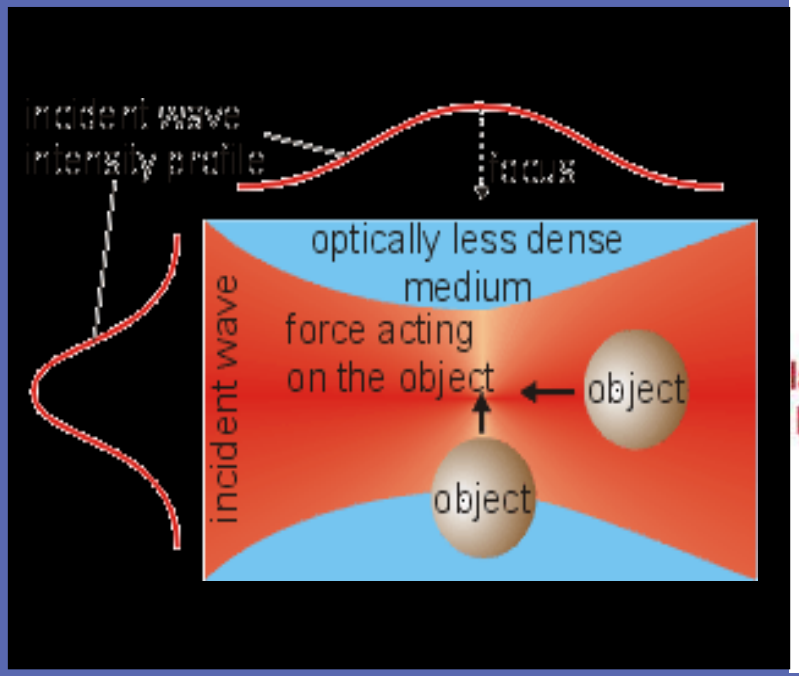
$$= \frac{2\pi(S\,c\Delta t)}{\frac{\Delta t}{S}} = 2w$$

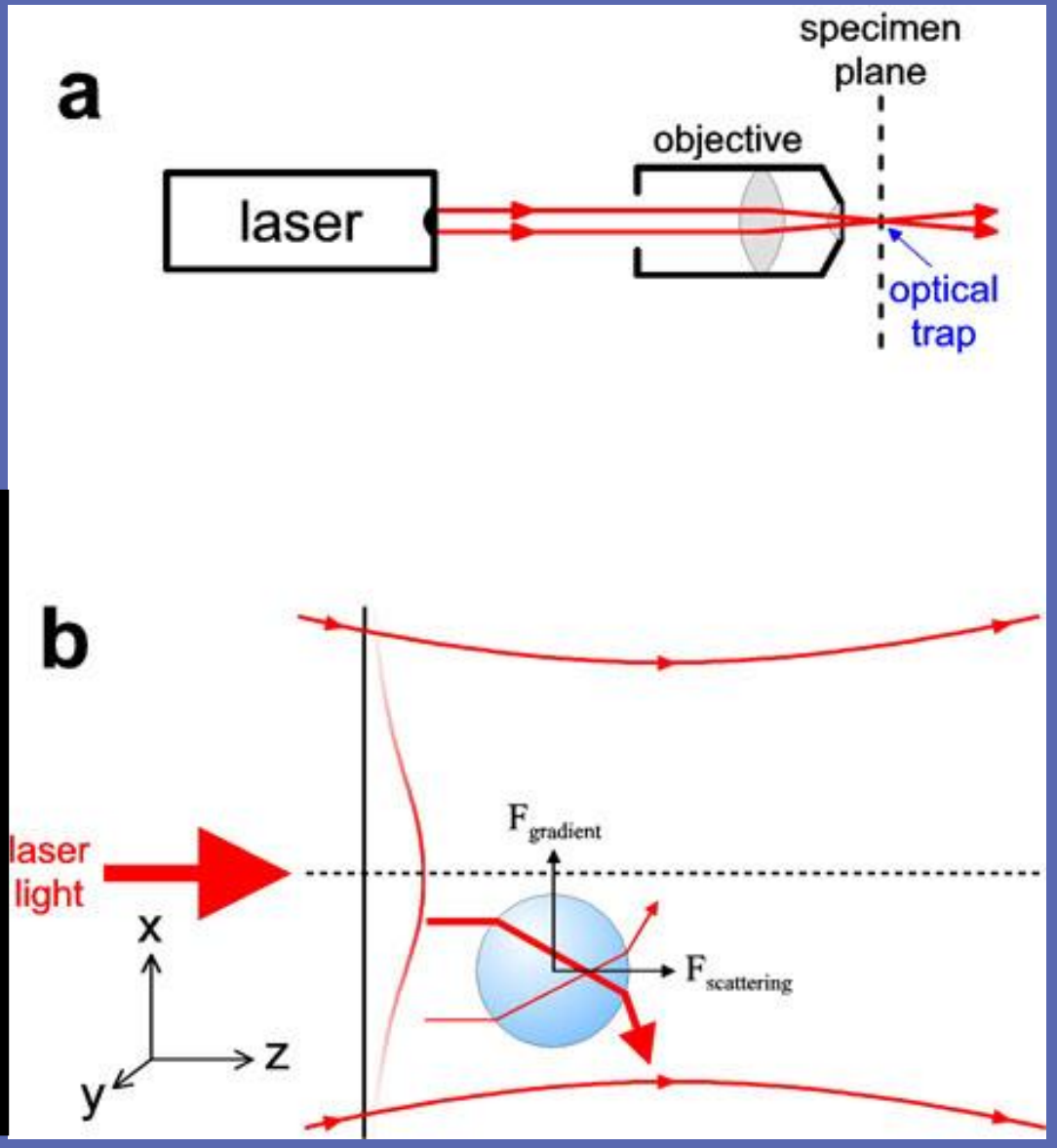
$$= 2\,I/c$$



The radiation of the Sun at the Earth has an energy flux density of 1370 W/m^2, so the radiation pressure is 1370 /299792458 Pa = 4.6 μPa (absorbed)

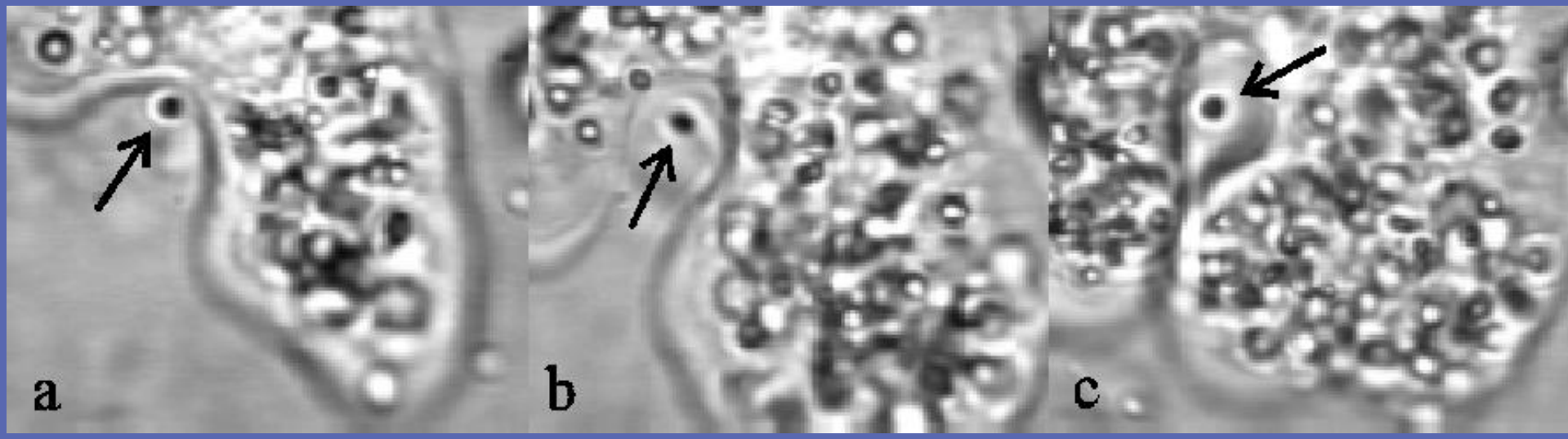
laserová pinzeta





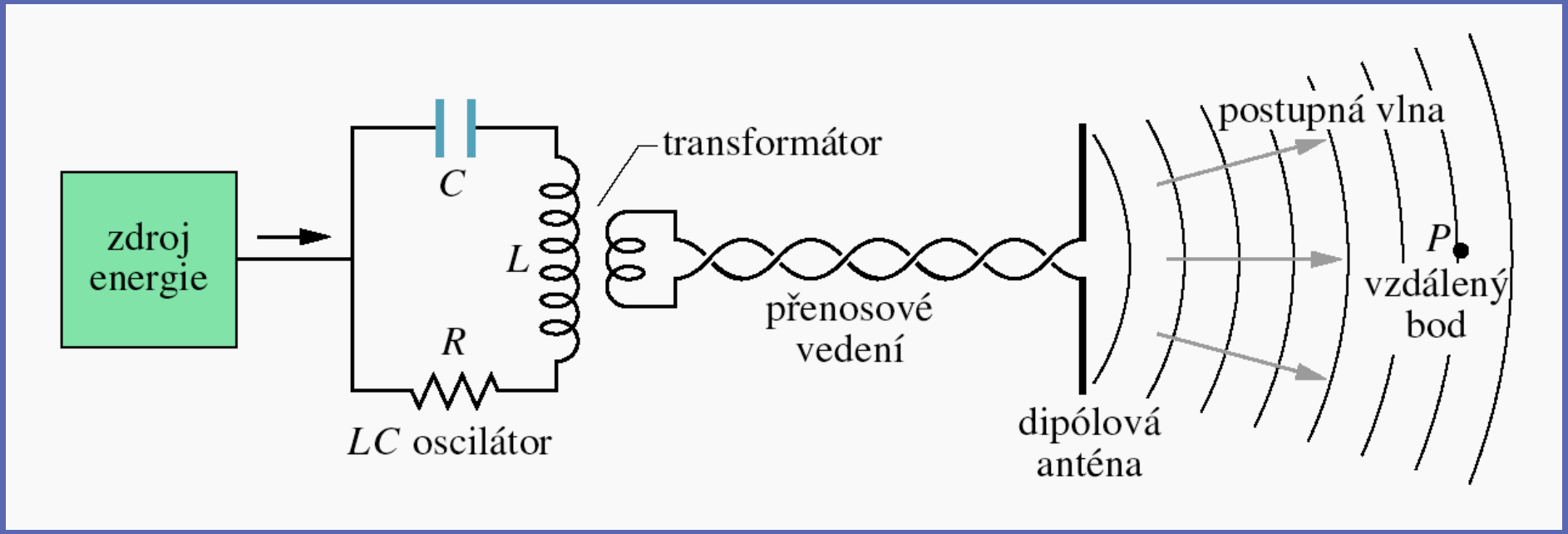
Optická (laserová) pinzeta je zařízení, které využívá mechanického účinku fokusovaného laserového svazku k prostorovému zachycení a přemísťování mikroobjektů a nanoobjektů.

„krmení“ améby bakteriální buňkou



(Tým optických mikromanipulačních technik ÚPT AVČR)

generace elektromagnetických vln



příjem elektromagnetických vln