Elektrostatik

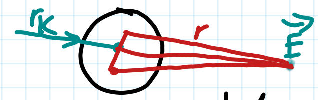
$$\vec{E} = \frac{1}{4\pi\cdot\varepsilon_0}\cdot\frac{q}{r^2}\,\hat{r}$$

mehrere Punktladungen: $\vec{E} = \sum \vec{E}_i = \frac{1}{4\pi\varepsilon_0}\cdot\sum\frac{q_i}{r_i^2}\,\hat{r}$

Ladungsdichte

$\rho = \frac{q}{V}$ $[\rho] = \frac{C}{m^3}$

$[E] = N/C$



Homogen geladene Kugel

$r > r_K$

$r < r_K$: $\vec{E} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{r}{r_K^3}\,\hat{r}$

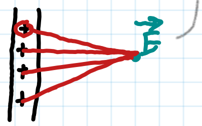
$$\vec{E} = \int d\vec{E} = \frac{1}{4\pi\varepsilon_0}\int\frac{dq}{r^2}\,\hat{r}$$

z.B $E_x = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}\;(\cos(\alpha))$

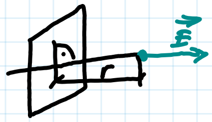
$\vec{E} = \frac{1}{2\pi\varepsilon_0}\cdot\frac{\lambda}{r_\perp}\,\hat{r}_\perp$ — Linienladungsdichte

$[\lambda] = \frac{C}{m}$

Linienladung



Platte



σ = Flächenladungsdichte

$[\sigma] = \frac{C}{m^2}$

Elektrische potenzielle Energie

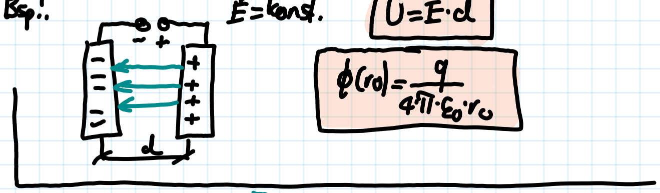
$\vec{F}_{el} = q_0\cdot\vec{E}$ $\Delta E_{pot} = q_0\cdot E\cdot\Delta h$

elektrische Potenzial

$\Delta\phi = E\cdot\Delta h$ $\phi = \frac{E_{pot}}{q_0}$ $[\phi] = \frac{J}{C} = V$

Potentialdifferenz = Spannung $U = \Delta\phi$

Bsp.: $\vec{E}$ = konst. $U = E\cdot d$



$\phi(r_0) = \frac{q}{4\pi\cdot\varepsilon_0\cdot r_0}$

Magnetismus

$[\vec{B}] = T$

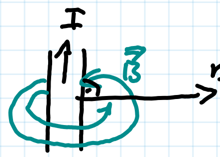
$\vec{F} = q\cdot\vec{v}\times\vec{B}$ $|\vec{F}| = |q|\cdot|\vec{v}|\cdot|\vec{B}|\cdot\sin(\alpha)$

$F = I\cdot\vec{l}\times\vec{B}$

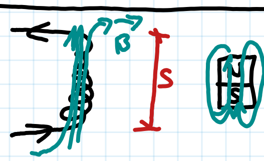
Periode $T = \frac{2\pi\cdot m}{q\cdot B}$

⊗ Weg von mir ⊙ zu mir

$r = \frac{m\cdot v}{q\cdot B}$



$\vec{B} = \frac{\mu_0}{2\pi}\cdot\frac{I}{r}$



$|\vec{B}| = \mu_0\cdot\frac{N}{s}\cdot I$ — Anz Windungen, Länge Spule

$B = \mu_{rel}\,\mu_0\,\frac{N}{s}\,I$ — Materialkonstante

Magnetischer Fluss:

$\Phi_m = N\cdot\vec{A}\cdot\vec{B} = N\cdot A\cdot B\cdot\cos(\alpha)$

Windungen (auch ohne N) Fläche

$U_{ind} = -\frac{d\Phi_m}{dt}$

Bsp: Generator

Winkelgeschw.

$\theta = \omega\cdot t$ $\Phi_m = (N)\cdot\vec{A}\cdot\vec{B} = (N)\cdot A\cdot B\cdot\cos(\omega\cdot t)$

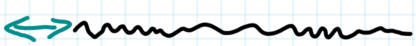
$U_{ind} = N\cdot A\cdot B\cdot\sin(\omega t) = U_0\cdot\sin(\omega\cdot t)$ — Amplitude

$[\Phi_m] = Vs$

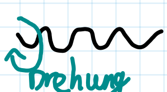
Wellen

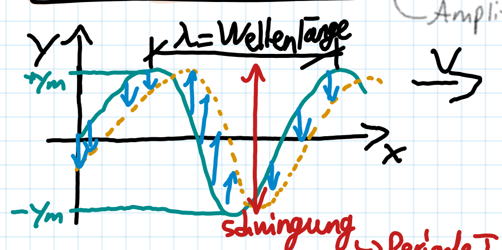
Arten: Transversale Welle

- longitudinale Welle



- Torsionswelle





Seilwelle: $v = \sqrt{\frac{F_S}{\mu}}$ $\Delta m = \mu\cdot\Delta x$ $[\mu] = kg/m$

$y(x,t) = y_m\cdot\sin\left(\underbrace{\frac{2\pi}{\lambda}}_{k}\cdot x - \underbrace{\frac{2\pi}{T}}_{\omega}\cdot t\right) + \phi$

− Wellenrichtung → +
+ Wellenrichtung → −

Wellenzahl $k = \frac{2\pi}{\lambda}$ $[k] = 1/m$

$\omega = \frac{2\pi}{T}$ $v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda\cdot f$

$E_{kin} = \frac{1}{2}\Delta m\,v_y^2$ $\Delta E_{mech} = \Delta E_{kin,max} = \frac{1}{2}\Delta m\cdot\omega^2\,y_m^2$

$P = \frac{\Delta E}{\Delta t} = \frac{1}{2}\cdot\mu\cdot\frac{\Delta x}{\Delta t}\cdot\omega^2\cdot y_m^2$

v = Wellengeschw.

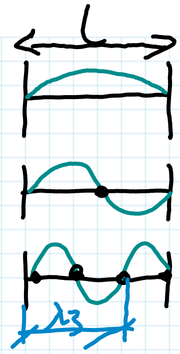
transversale Geschw.: $v_y = \frac{dy}{dt}$

Superposition Wellen (Interferenz)

konstruktive Interferenz: Wellen summieren sich
destruktive " : Wellen eliminieren sich

2 feste Enden

$\boxed{f_n = n \cdot f_1}$



$\lambda_1 = 2L$ $\quad f_1 = \frac{v}{\lambda_1} = \frac{v}{2L}$

$\lambda_2 = L$ $\quad f_2 = \frac{v}{\lambda_2} = \frac{v}{L} = 2 \cdot f_1$

$\lambda_3 = \frac{2}{3} L$ $\quad f_3 = \frac{v}{\lambda_3} = \frac{3v}{2L} = 3 \cdot f_1$

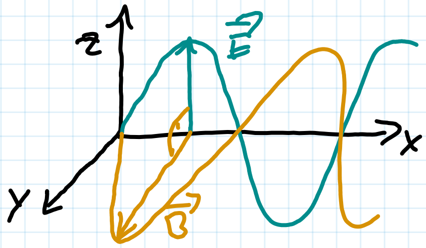
Elektromagnetische Wellen Vakuum

$\vec{E}(x,t) = \vec{E}_0 \cdot \sin(kx - \omega t)$

$\vec{B}(x,t) = \vec{B}_0 \cdot \sin(kx - \omega t)$

Wellengeschw. $v = c = 3 \cdot 10^8 \, m/s$

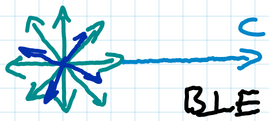
$\vec{E} \times \vec{B}$ $\quad \boxed{|\vec{B}_0| = \frac{|\vec{E}_0|}{c}}$



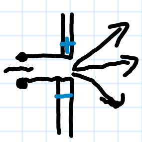
EM-Wellen allg.

$\boxed{c = \lambda \cdot f}$

unpolarisierte Welle

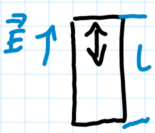


Antenne

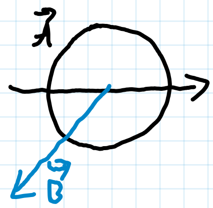


Empfänger optimal $\parallel \vec{E}$

Stabantenne



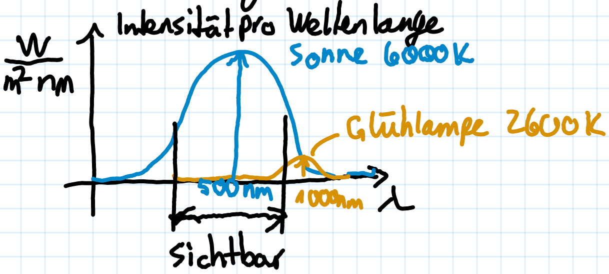
$\boxed{U_{ind} = E \cdot L}$



$\boxed{\Phi = \vec{A} \cdot \vec{B}}$

$\boxed{U_{ind} = -\frac{d\Phi_m}{dt} = -A \cdot \frac{dB}{dt}}$

Wärmestrahlung



Max. des Spektrums

$\lambda_{max} = \frac{2.9 \cdot 10^{-3} m \cdot K}{T}$ $\quad [\lambda] = m$

T → Temp. in Kelvin

Energie EM-Welle

$\boxed{w_{el} = \frac{\text{Energie}}{\text{Volumen}} = \frac{1}{2} \cdot \varepsilon_0 \cdot E^2}$ $\quad [w_{el}] = J/m^3$

Energiedichte

$\boxed{w_{mag} = \frac{1}{2\mu_0} \cdot B^2}$

$\boxed{w_{EM} = w_{el} + w_{mag} = 2 w_{el} = \varepsilon_0 \cdot E^2}$

$\boxed{\text{Intensität} = \frac{\text{durchsch. Leistung}}{\text{Fläche}} = \text{durchschn. } w_{EM} \cdot c}$

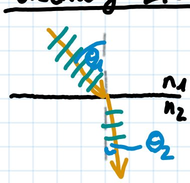
$\boxed{\frac{P}{A} = I_{EM} = \frac{1}{2} \varepsilon_0 \cdot c \cdot E_0^2 = \frac{c}{2\mu_0} B_0^2}$ $\quad [I_{EM}] = \frac{W}{m^2}$

Licht als EM-Welle

$\boxed{c_n = \frac{c}{n}}$

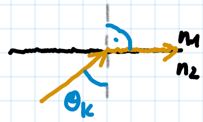
c_n: v in Material; c: Lichtgeschw.; n: Berechnungsindex

Brechung Licht



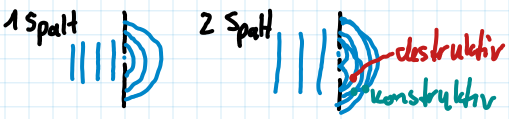
$\boxed{n_1 \cdot \sin(\theta_1) = n_2 \cdot \sin(\theta_2)}$

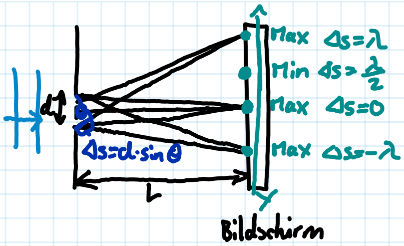
Totale Reflexion



$\boxed{\theta_K = \arcsin\left(\frac{n_2}{n_1}\right)}$

Interferenz am Doppelspalt





konstruktiv

$\boxed{d\cdot\sin\theta = m\cdot\lambda}$

$\boxed{L\cdot\sin\theta_4 = m\,\frac{L\cdot\lambda}{d}}$

$\boxed{\Delta s = m\,\lambda = d\cdot\sin\theta}$

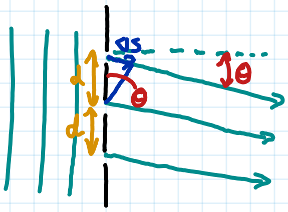
Wegdifferenz/ Gangunterschied

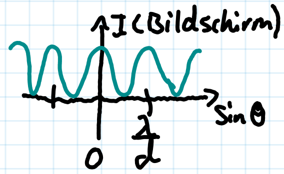
destruktiv

$\boxed{d\cdot\sin\theta = (m+\tfrac{1}{2})\,\lambda}$

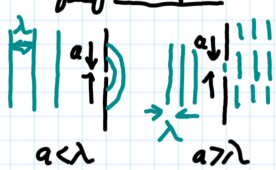
$m = 0, \pm 1, \pm 2, \pm 3 \ldots$

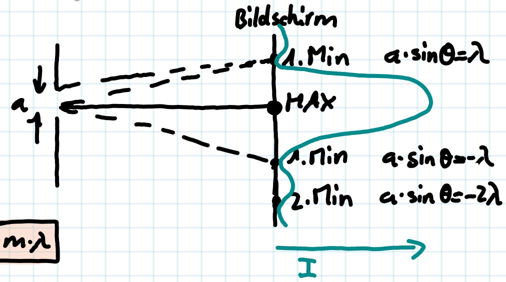
Bewegungsgitter





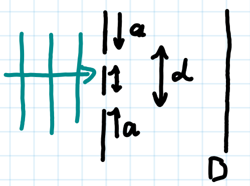
Beugung am Spalt





Beugungsminima: $\boxed{a\cdot\sin\theta = m\cdot\lambda}$

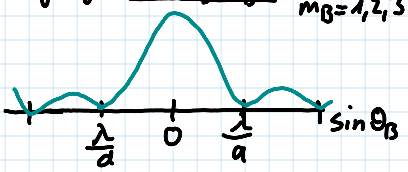
Beugung am Doppelspalt

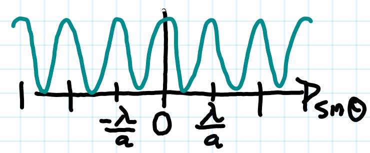


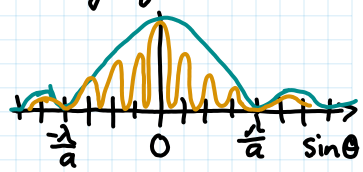
Beugung: $\boxed{a\sin\theta_B = m_B\,\lambda} \Rightarrow$ Min $m_B = 1, 2, 3$

Interferenz: $\boxed{d\cdot\sin\theta = m\cdot\lambda} \Rightarrow$ MAX

Beugung + Interferenz







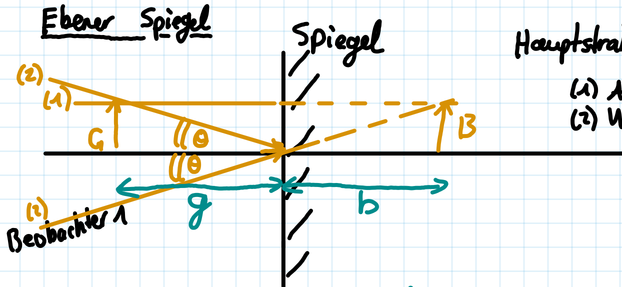
Auflösung opt. Instrumente

Auflösung $\propto \frac{\lambda}{D}$

besser für λ klein

besser für D gross

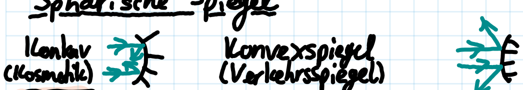
Ebener Spiegel



Hauptstrahlen.

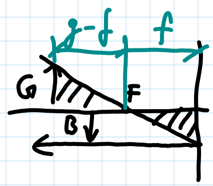
(1) Achsenparallel
(2) Winkel θ zu opt. Achse

Sphärische Spiegel



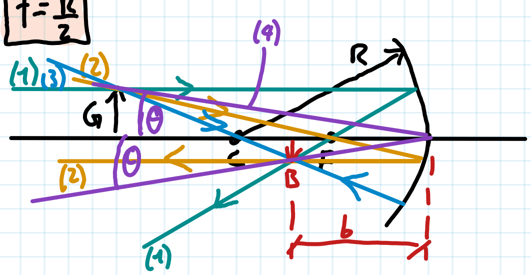
$\boxed{f = \frac{R}{2}}$

Strahl(2)



$\boxed{\frac{G}{g-f} = -\frac{B}{f}}$ $\boxed{\frac{g-f}{f} = -\frac{G}{B}}$

$\boxed{\frac{1}{f} = \frac{1}{b} + \frac{1}{g}}$



Hauptstrahlen:

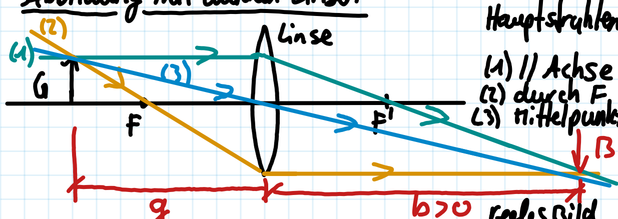
(1) // Achse ⇒ durch F
(2) durch F ⇒ // Achse
(3) Mittelpunktstrahl durch C ⇒ durch C
(4) θ zur Achse = -θ zur Achse

$\boxed{\frac{G}{g} = -\frac{B}{b}}$ $\boxed{V = \frac{B}{G} = -\frac{b}{g}}$

$G > 0$

$B < 0$ (Bild auf Kopf)

Abbildung mit dünnen Linsen



Hauptstrahlen:

(1) // Achse ⇒ durch F'
(2) durch F ⇒ // Achse
(3) Mittelpunktstrahl

$\boxed{\frac{1}{f} = \frac{1}{g} + \frac{1}{b}}$ $\boxed{V = \frac{B}{G} = -\frac{b}{g}}$ $\boxed{B = \frac{1}{f}}$ $[B] = 1\,m^{-1} = 1\,D$ (Dioptrie)

Radioaktivität

Bestandteile

Nukleonen { Protonen (p), Neutronen (n)

Bsp: $^{A}_{Z}Li$

A = Massenzahl = $Z+N$ (Neutronen)

Z = Ordnungszahl (Anz. Protonen)

Isotope

Nuklide mit gleichem Z aber untersch. N

Kernradien

$r \approx (1{,}2\,fm)\cdot A^{\frac{1}{3}}$ – Massenzahl

$m(Kern) < m(Bestandteil)$

$1u\cdot c^2 = 931.5\,MeV$

atomare Masseneinheiten

Bindungsenergie

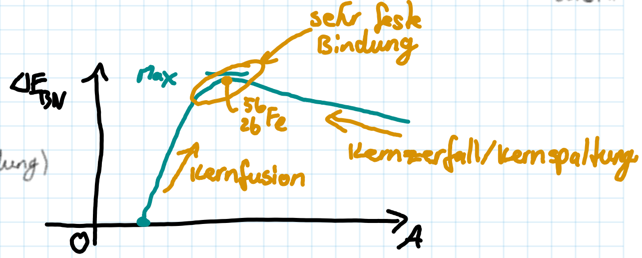
$$\boxed{\Delta E_B = \sum_{i=1}^{A}(m_i\cdot c^2) - m_K\cdot c^2}$$

Je grösser Kerne desto grösser ΔE_B

$$\boxed{\Delta E_{BN} = \frac{\Delta E_B}{A}}$$

(Wie fest Bindung)

Bindungsenergie pro Nukleon



Radioaktiver Zerfall

Zerfallskonstante

N = Anz Kerne $\boxed{\frac{dN}{dt} = -\lambda\cdot N}$ $[\lambda] = 1/s$

Lösung: $\boxed{N(t) = N_0\cdot e^{-\lambda\cdot t}}$

$\boxed{T_{1/2} = \frac{\ln(2)}{\lambda}}$

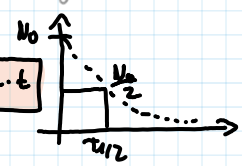
Zerfallsrate = Aktivität $[R] = 1\,Bq = 1\,Zerfall/sek$

$$\boxed{R = -\frac{dN}{dt} = +\lambda N = +\lambda\cdot N_0\cdot e^{-\lambda\cdot t} = R_0\cdot e^{-\lambda\cdot t}}$$

Anz. Kerne

$\boxed{N = \frac{m}{M}\cdot N_A}$ – Molmasse, Avogadrozahl

$\boxed{N(t) = N_0\cdot e^{-\frac{\ln(2)}{T_{1/2}}\cdot t}}$



α-Zerfall

$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He + Q$ ← Tritt spontan auf

M_i (Mutterkern), M_f (Tochterkern), Energie

Transmutation

Energieerhaltung

$\boxed{M_i\cdot c^2 = M_f\cdot c^2 + Q}$ $\boxed{Q = \Delta M\cdot c^2} = (M_a + M_x - M_b - M_y)\cdot c^2 = E_{kin}$

Zerfallsenergie

β-Zerfall

– β^--Zerfall

Kern → e^- Elektron

Anz. Nukleonen ist erhalten

el. Ladung ist erhalten

z.B. $^{32}_{15}P \rightarrow {}^{32}_{16}S + e^- + \bar{\gamma}$

$n \rightarrow p + e^- + \bar{\nu}_e$

Neutrino

– β^+-Zerfall

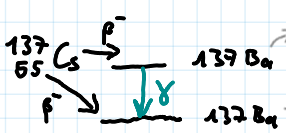
Kern → e^+ (Positron), ν_e Neutrino

z.B. $^{64}_{29}Cu \rightarrow {}^{64}_{28}Ni + e^+ + \nu_e$

$p \rightarrow n + e^+ + \nu_e$

γ-Zerfall

Kern → γ-Teilchen (Photon)



angeregter Zustand

Grundzustand

Zerfallsreihen

$^{238}U \rightarrow {}^{234}Th \rightarrow {}^{234}Pa \rightarrow {}^{234}U \rightarrow \ldots + {}^{206}Pb$

Blei

Absorptionsgesetz

$$\boxed{I(x) = I_0\cdot e^{-\mu\cdot x}}$$

x – Dicke Material; μ – Absorptionskoeffizient

Energiedosis

$\boxed{D = \frac{E_{abs}}{m}}$ $[D] = 1\,Gray = 1\,J/kg = 1\,Gy$

Energiedosis, Energie, Masse

Äquivalentdosis

$\boxed{H = Q\cdot D}$ $[H] = Sievert = Sv = 1\,J/kg$

Äquivalentdosis, Qualitätsfaktor, Energiedosis