2013.09.18.
1. gyakorlat

Lorentz-erő: $\underline{F} = q(\underline{v} \times \underline{B})$

a sebesség merőleges a mágneses ind.

Ha $\underline{v} \perp \underline{B}$-re → folyamatosan körpályán mozog a részecske.

## 30A-5

B (mágneses indukció) = 0,5 T
R = 1 cm

$$q \cdot v \cdot B = m \cdot \frac{v^2}{r}$$

$$E_m = \frac{1}{2} m v^2 \rightarrow v^2 = \frac{2 \cdot E_m}{m} \rightarrow v = \sqrt{\frac{2 \cdot E_m}{m}}$$

$$q \cdot \sqrt{\frac{2 E_m}{m}} \cdot B = m \cdot \frac{\frac{2 E_m}{m}}{R}$$

proton tömege $(m) = 1{,}67 \cdot 10^{-27}$ kg
töltése $q = 1{,}6 \cdot 10^{-19}$ C

$$E_m = \frac{(q \cdot B \cdot R)^2}{2m} =$$

$$= \frac{(1{,}6 \cdot 10^{-19}\,C \cdot 0{,}5\,T \cdot 10^{-2}\,m)^2}{2 \cdot 1{,}67 \cdot 10^{-27}\,kg} = 1197{,}6\ eV = \underline{\underline{1{,}19}}\ keV$$

## 30B-14

B = 50 μT (felfelé mutat É-i irányba)
$E = 100\ \frac{N}{C}$ (lefelé mutat)
$E_m = 100$ eV ($1\ eV = 1{,}6 \cdot 10^{-19}$ J)
$e^-$ tömege $m = 9{,}1 \cdot 10^{-31}$ kg
$q = 1{,}6 \cdot 10^{-19}$ C

$$E_m = \frac{1}{2} m v^2 \Longrightarrow v = \sqrt{\frac{2 E_m}{m}} = \sqrt{\frac{2 \cdot 100 \cdot 1{,}6 \cdot 10^{-19}\,J}{9{,}1 \cdot 10^{-31}\,kg}} =$$

$$= \underline{\underline{5{,}93 \cdot 10^6\ \frac{m}{s}}}$$

$G = m \cdot g = 9{,}1 \cdot 10^{-30}$ N

$F_e = q \cdot E = 1{,}6 \cdot 10^{-17}$ N

$F_M = q \cdot \underline{v} \cdot \underline{B} = 4{,}76 \cdot 10^{-17}$ N

$$\boxed{\underline{F} = q(\underline{E} + \underline{v} \times \underline{B})}$$

30B-12

$E_m = 2\,keV$
$B = 50\,\mu T$

Lorentz-erő = tömeg · centripetális gyorsulás

a) $R = ?$ (pálya sugara)

$$q \cdot v \cdot B = m\frac{v^2}{R} \longrightarrow v = \sqrt{\frac{2E_m}{m}} = \sqrt{\frac{2 \cdot 2 \cdot 10^3 \cdot 1{,}6 \cdot 10^{-19}\,J}{9{,}1 \cdot 10^{-31}\,kg}} =$$

$$= \underline{\underline{2{,}65 \cdot 10^7}}\ \frac{m}{s}$$

$$R = \frac{m \cdot v}{q \cdot B} \approx \underline{\underline{3\,m}}$$

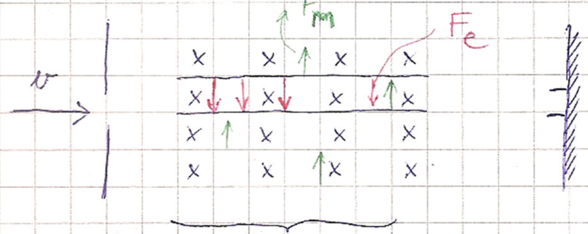
b) $v = \omega \cdot R = 2\pi \cdot f$

$$R = 2\pi \cdot f \cdot \frac{mv}{qB} \longrightarrow f = \frac{B}{2\pi} \cdot \frac{q}{m} = 1{,}4 \cdot 10^6\ \frac{1}{s} \approx 16\ \frac{1}{nap}$$

30B-15

$B = 0{,}015\ T$

$E_m = 750\ eV$



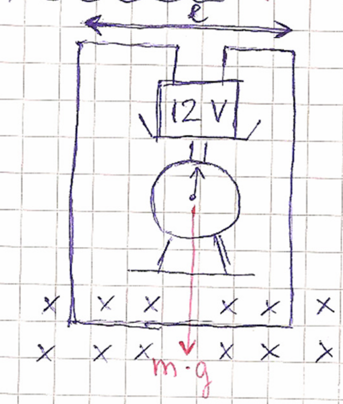

mágneses + elektromos } egymásra merőlegesek!!
tér / mező

$$q \cdot E = q(v \times B) = q \cdot v \cdot B \implies v = \frac{E}{B}$$ → elektromos tér

$$v = \sqrt{\frac{2E_m}{m}} = \sqrt{\frac{2 \cdot 750 \cdot 1{,}6 \cdot 10^{-19}\,J}{9{,}1 \cdot 10^{-31}\,kg}} = 1{,}6 \cdot 10^7\ \frac{m}{s}$$

$$E = 1{,}6 \cdot 10^7\ \frac{m}{s} \cdot 0{,}015\ T = 2{,}4 \cdot 10^5\ \frac{V}{m} \qquad \left(T = \frac{V \cdot s}{m^2}\right)$$

## 30A - 16 (ZH feladat)




$U = 12\ V$

$B = 0{,}1\ T$

$\ell = 20\ cm = 0{,}2\ m$

$m = 100g = 0{,}1\ kg$

$F = q \cdot v \cdot B$

$F = n \cdot q \cdot v \cdot A \cdot \ell \cdot B$

$I = n \cdot q \cdot v \cdot A$

$F = I \cdot \ell \cdot B$

általánosan: $F = I\ \boldsymbol{\ell} \times B$

áramvezetőre ható erő

$G = m \cdot g$

$F = I \cdot \ell \cdot B$

$I = \dfrac{F}{\ell \cdot B}$

$|F| = |G|$

$I = \dfrac{1N}{0{,}2\ m \cdot 0{,}1\ T} = 50\ A$

$R = \dfrac{U}{I} = \dfrac{12\ V}{50\ A} = 0{,}24\ \Omega$

## 30A - 24 (HALL - effektus)


Egyensúly esetén: $|F_e| = |F_M|$

$e \cdot E = e \cdot v_e \cdot B$

$E = v_e \cdot B$

$E = \dfrac{I}{n \cdot e \cdot A} \cdot B$

$I = n \cdot e \cdot v_e \cdot A$

$A = a \cdot b$

$v_e = \dfrac{I}{n \cdot e \cdot A}$

n → elektronok / részecskék száma

$E \cdot a = \dfrac{I\ B}{n \cdot e \cdot b}$

⇓

$U_H$ = HALL - feszültség

$U_H = \dfrac{I \cdot B}{n \cdot e \cdot b}$

$a = 4\ cm$
$b = 0{,}1\ mm$
$I = 5\ A$
$B = 0{,}15\ T$

$\rho_{ezüst} = 10{,}5\ g/cm^3$

$m = 107{,}87\ \dfrac{g}{mol}$

$n = \dfrac{\rho \cdot N_A}{m} = \dfrac{10{,}5 \cdot 10^6\ \frac{g}{m^3} \cdot 6{,}022 \cdot 10^{23}\ \frac{elektron}{mol}}{107{,}87\ g/mol} =$

$= 5{,}86 \cdot 10^{28}\ \dfrac{elektron}{m^3}$

$U_H = 8 \cdot 10^{-7}\ V$

Gerjesztési-törvény: $\oint B\,dl = \mu_0 \sum I$

Bármely zárt görbére

Fluxus: $\phi = B \cdot A$

31A-13

Szolenoid


$B = 0{,}07\ T$
$d = 2\ cm$
$L = 50\ cm$

$B \cdot L = \mu_0 \sum I = \mu_0 \cdot N \cdot I$

$B = \mu_0 \cdot \frac{N \cdot I}{L}$

a)
$\phi = BA = B \cdot R^2 \cdot \pi = B \cdot \left(\frac{d}{2}\right)^2 \cdot \pi = 2{,}2 \cdot 10^{-5}\ Tm^2\ (Wb)$

b) $N = ?$ $\quad N = \frac{B \cdot L}{I \cdot \mu_0} =$ $\quad \mu_0 = 4\pi\, 10^{-7}\ \frac{Tm}{A}$

$= 5570$ (tekercselés fél méteren)

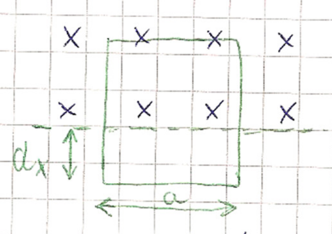
—o—

Mozgási indukció

Faraday-törvény: $U = -\frac{\partial \phi}{\partial t}$

—o—

32B-5




$U = -\frac{\partial \phi}{\partial t} = -\frac{\partial}{\partial t}(B \cdot A) = -B\frac{\partial A}{\partial t} = -B \cdot a \frac{dx}{\partial t} = -Bav$

$F_M = G$
$I a B = m \cdot g$ $\Big\} \Rightarrow I = \frac{mg}{Ba}$ $\quad R = \frac{U}{I}$ $\quad U = \frac{m \cdot g \cdot R}{B \cdot a^2}$

2013. 10. 02.

# 2. gyakorlat

$\mu = \mu_0 (1 + \chi)$

↳ szuszceptibilitás

$\chi << 1$ diamágnes

$\chi > 0$ paramágnese

## 33A.-1

$L = 20$ cm
$N = 700$ szolenoid
$d = 14$ cm
$\phi = 3 \cdot 10^{-4}$ Tm² közepén

$I = ?$
$\chi = 5000$

Gerjesztési törvény
↓
$B \cdot L = \mu \cdot I \cdot N$

$\phi = B \cdot A = B \cdot \left(\frac{d}{2}\right)^2 \pi \Rightarrow B = \frac{4\phi}{d^2 \pi}$

$$\frac{4 \phi L}{d^2 \pi} = \mu_0 (1 + \chi) I N \Longrightarrow I = 88{,}6 \text{ mA}$$

## 33A-2

$\chi = 1{,}8 \cdot 10^{-5}$ (valószínűleg paramágneses anyag)
$\mu = ?$

$$\mu = \mu_0 \underbrace{(1 + \chi)}_{\mu_r}$$

$\mu_r$ → relatív permeabilitás

$$\mu = 4 \cdot \pi \cdot 10^{-7} \frac{T \cdot m}{A} (1 + 1{,}8 \cdot 10^{-5})$$

$$\mu = 1{,}256 \cdot 10^{-6} \frac{Tm}{A}$$

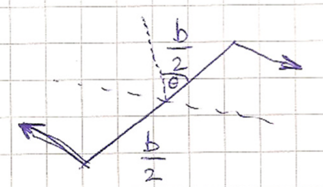
## 34-B4 váltakozó áramú generátor

$\phi(t) = B \cdot A \cdot \cos(\omega t)$

$I(t) = \frac{u(t)}{R} = \frac{B}{R} \cdot A \cdot \omega \cdot \sin(\omega t)$

$u = \frac{\partial \phi(t)}{\partial t}$

$u(t) = A \cdot B \cdot \omega \cdot \sin(\omega t)$



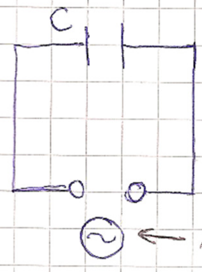

$F = I \cdot a \cdot B$

$M = F\left(\frac{b}{2}\right) \sin\theta + F\left(\frac{b}{2}\right) \sin\theta$

$$M = F \cdot b \cdot \sin(\omega t) = I \cdot a \cdot b \cdot \sin(\omega t) = \frac{B}{R} \cdot a \cdot b \cdot \cos(\omega t) \cdot a \cdot b \cdot \sin(\omega t) =$$

$$= \frac{\omega \cdot (B \cdot ab)^2}{R} \sin^2(\omega t)$$

## 34A – 2




← váltakozó áram jele

$$u(t) = u_0 \cdot \sin(\omega t)$$

$$I(t) = I_0 \cdot \sin(\omega t)$$

$$u(t) = \frac{Q(t)}{C}$$

$Q(t)$ ← időben változó töltés

$C$ ← kondenzátor kapacitása

$$\frac{\partial Q}{\partial t} = C \cdot \frac{\partial u(t)}{\partial t} \qquad I(t) = \frac{u_0}{X_c} \cdot \cos(\omega t)$$

$$X_c = \frac{1}{\omega \cdot c}$$

$X_c$ → reaktancia

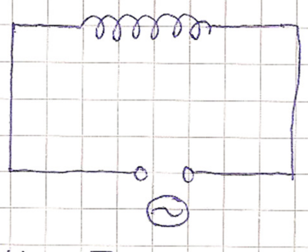
a)

$C = 8\,\mu F$
$f = 50\ Hz$
$\omega = 2\pi f$

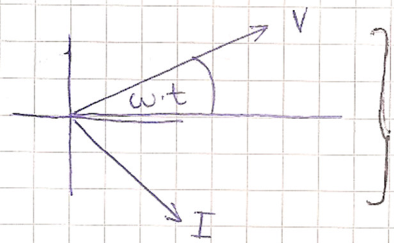
$$X_c = \frac{1}{\omega \cdot c} = 397{,}88\ \Omega$$

$$f = 5\ kHz \longrightarrow X_c = 398\ \Omega$$

b) $L :=$ induktivitás

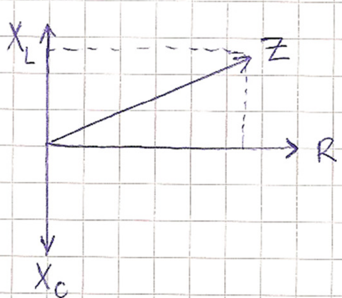


$$X_L = \omega \cdot L$$




Fázis-diagram

$u - I$ :




$$Z^2 = R^2 + (X_L - X_c)^2 \qquad \operatorname{tg} \varphi = \frac{X_L - X_c}{R}$$

## 34A – 8

$R = 30\ \Omega$
$L = 15\ mH$
$C = 10\ \mu F$
$u = \underbrace{100}_{u_0} \cdot \sin(\underbrace{2500 \cdot t}_{\omega})$

$$W = \frac{1}{2} L I^2 \qquad I(t) = \frac{u(t)}{Z} = \frac{u_0}{Z}$$

$$Z = \sqrt{R^2 + (X_L - X_c)^2} = 30{,}1\ \Omega$$

$X_L \to L\omega$, $X_c \to \frac{1}{\omega \cdot c}$

$$W = \frac{1}{2} L I^2 = \frac{1}{2} L \left(\frac{u_0}{Z}\right)^2 = 0{,}08\ J$$

kondenzátor energiája $W = \frac{1}{2} C u^2$

34 - B12 aluláteresztő szűrő (TV-kben zajszűrőként használják)

$U_{be} = I(t) \cdot R + I(t) \cdot X_c$

$U_{ki} = I(t) \cdot X_c$

$\frac{U_{ki}}{U_{be}} = \frac{I(t) \cdot X_c}{I(t)(R + X_c)} = \frac{\frac{1}{\omega \cdot c}}{R + \frac{1}{\omega \cdot c}} = \frac{1}{R \cdot \omega c + 1}$

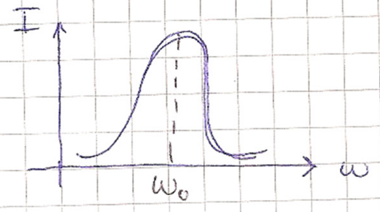
34A - 18

RLC → rezgőkör

$Z = \sqrt{R^2 + (X_L - X_c)^2}$

$I_{eff} = \frac{U_{eff}}{Z} = \frac{U_{eff}}{\sqrt{R^2 + (X_L - X_c)^2}}$

maximális, ha $X_L = X_c$




$\frac{1}{\omega_0 \cdot C} = \omega_0 \cdot L \Longrightarrow \omega_0 = \frac{1}{\sqrt{L \cdot C}}$

$f_0 = 1070$ kHz

a) $L = ?$
$C = 0{,}2$ μF

$L = \frac{1}{\omega_0^2 \cdot C} = 1{,}1 \cdot 10^{-2}$ H

b) $R = ?$
$Q = 70$ → jósági tényező (mértékegység nélküli mennyiség)

$Q = \frac{L \cdot \omega_0}{R} \Longrightarrow R = \frac{L \cdot \omega_0}{Q}$

$R = 0{,}01\ \Omega$

$P = I \cdot U$

# 3. gyakorlat

2013. 10. 16.

**34A - 25**

$R = 100\,\Omega$

$U_0 = 156\ V$ → váltóáram

$P = ?$

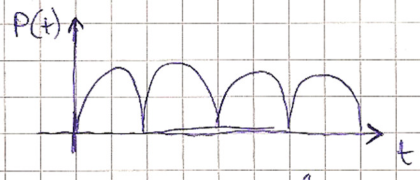
$P(t) = U(t) \cdot I(t)$

$U(t) = U_0 \cdot \sin(\omega \cdot t)$

$I(t) = I_0 \cdot \sin(\omega \cdot t)$

$$I(t) = \frac{U(t)}{R} = \frac{U_0 \cdot \sin(\omega \cdot t)}{R}$$

$$P(t) = \frac{U_0^2}{R} \sin^2(\omega \cdot t)$$




$$P_{átl} = \langle I(t) \cdot U(t) \rangle = \frac{1}{T} \cdot \int P(t)\, dt = \frac{U^2}{2R}$$

**34B - 33**

$U_{eff} = 110\ V$

$f = 60\ Hz$

$P = 480\ W$

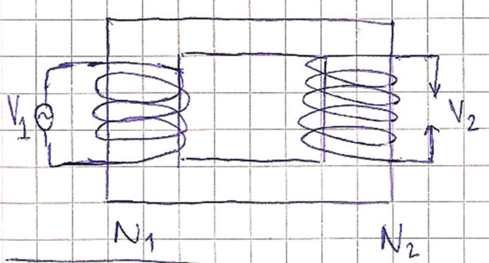
$U(t) = U_0 \cdot \sin(\omega \cdot t)$

$I(t) = I_0 \cdot \sin(\omega \cdot t - \varphi)$

$P(t) = U(t) \cdot I(t)$

$$P_{átl} = \frac{1}{T} \cdot \int_0^T P(t)\, dt = \frac{U_0 \cdot I_0}{2} \underbrace{\cos\varphi}_{\text{teljesítmény tényező}}$$

Transzformátor




$$\frac{U_1}{N_1} = \frac{U_2}{N_2} \qquad \frac{U_1}{U_2} = \frac{I_1}{I_2} = \frac{N_1}{N_2}$$

$P_1 = P_2$

$U_1 I_1 = U_2 I_2$

**34B - 38**

$U_2 = 20\ kV$

$U_1 = 220\ V$

$I_2 = 11\ mA$

a) $\frac{N_1}{N_2} = ?$ $\qquad \frac{U_1}{U_2} = \frac{N_1}{N_2} = 0{,}011$

$N_2 = 90{,}9 \cdot N_1$

b) $P_1 = ?$ $\qquad P_1 = U_1 \cdot I_1 \qquad I_1 = \frac{N_2}{N_1} I_2 = 1\ A$

$P_1 = 220\ V \cdot 1\ A = 220\ W$

34B-40

$U_1 = 220\ V$
$U_2 = 12\ V$

8 db 40 W-os izzólámpa működik. $\Longrightarrow P_2$

a) $R = ?$ a kertben lévő rendszerben?

$$P_2 = U_2 \cdot I_2 \Longrightarrow I_2 = \frac{P_2}{U_2} = \frac{8 \cdot 40\ W}{12\ V} = 26{,}67\ A$$

$$R = \frac{U_2}{I_2} = 0{,}45\ \Omega$$

c) $R' = ?$, hogy $P_2 = P_1$?

$$U_1 I_1 = U_2 I_2 \Longrightarrow I_1 = \frac{U_2 I_2}{U_1} = 1{,}45\ A$$

$$R' = \frac{U_1}{I_1} = 151{,}72\ \Omega$$

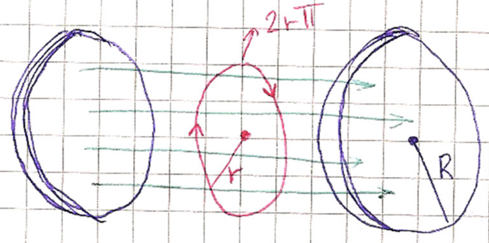
menetszámokkal kifejezve:

$$\left. \begin{aligned} U_2 &= \frac{N_2}{N_1} U_1 \\ I_2 &= \frac{N_1}{N_2} I_1 \end{aligned} \right\} \qquad \begin{aligned} U_2 &= R \cdot I_2 \\ \frac{N_2}{N_1} U_1 &= R \cdot \frac{N_1}{N_2} I_1 \end{aligned}$$

Maxwell egyenletek

$$\oint \underline{B}\, d\underline{l} = \mu_0 I + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} = \mu_0 \Big( I + \underbrace{\varepsilon_0 \frac{d\Phi_E}{dt}}_{\text{eltolási áram}} \Big) \qquad \Phi_E = \underline{E} \cdot \underline{A}$$

35B-6 35B-7 35B-2




$I = 0$

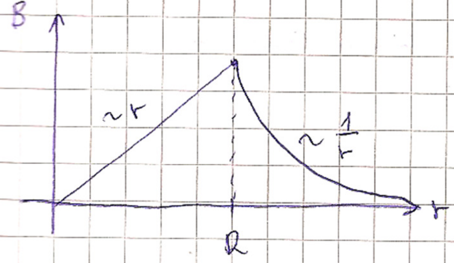
$$\oint \underline{B}\, d\underline{l} = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

Ha $r \leq R$

$$B(2r\pi) = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} \left(\frac{r}{R}\right)^2 \Longrightarrow \boxed{B = \frac{\mu_0 \varepsilon_0}{2\pi} \cdot \frac{d\Phi_E}{dt} \left(\frac{r}{R^2}\right)}$$

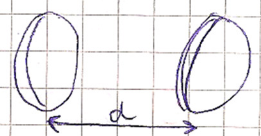
Ha $r \geq R$

$$B(2r\pi) = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} \Longrightarrow \boxed{B = \frac{\mu_0 \varepsilon_0}{2\pi} \frac{d\Phi_E}{dt} \cdot \frac{1}{r}}$$




$\frac{dV}{dt} \rightarrow$ potenciál sebesség megváltozása

$V = E \cdot d$




$$B = \frac{\mu_0 \varepsilon_0}{2\pi} \frac{r}{R^2} \frac{d}{dt}(E \cdot A) = \frac{\mu_0}{2\pi} \frac{r}{R^2} \frac{d}{dt}\left(V \cdot \underbrace{\frac{\varepsilon_0 \cdot A}{d}}\right)$$

kondenzátor kapacitása $\Downarrow$ C

$$B = \frac{\mu_0}{2\pi} \frac{C \cdot r}{R^2} \frac{dV}{dt} = \frac{4\pi \cdot 10^{-7}}{2\pi} \cdot \frac{C \cdot r}{R^2} \cdot \frac{dV}{dt} =$$

$$= 2 \cdot 10^{-7} \frac{C \cdot r}{R^2} \cdot \frac{dV}{dt}$$

Ha $r < R$

$$B = \frac{2C}{r} \frac{dV}{dt} \cdot 10^{-7}$$

35B - 2

$D = 10\ cm \rightarrow R = 5\ cm$
$d = 1\ mm$

$\frac{dV}{dt} = 1000 \frac{V}{s}$

$E = \frac{V}{d} \rightarrow$ lemezek távolsága

$B = ?$ a kondenzátor szélein? $(r = R)$

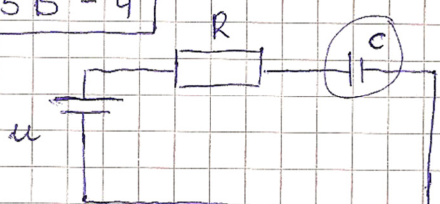
$$B(2\pi R) = \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt} = \mu_0 \varepsilon_0 (E \cdot A) \frac{d}{dt} =$$

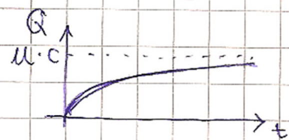
$A = R^2 \pi$

$$= \mu_0 \varepsilon_0 \frac{d}{dt}(E \cdot R^2 \pi)$$

$$B = \frac{\mu_0 \varepsilon_0}{2} R \frac{d}{dt} E = \frac{\mu_0 \varepsilon_0 R}{2d} \cdot \frac{dV}{dt} \Longrightarrow B = 2{,}78 \cdot 10^{-13}\ T$$

35B - 4




$$Q = u \cdot C\left(1 - e^{-\frac{t}{RC}}\right)$$

$C = 0{,}5\ \mu F$
$R = 100\ \Omega$
$u = 9\ V$

$I_d = ?$

$$I_d = \varepsilon_0 \frac{d\Phi_E}{dt} = \varepsilon_0 \frac{d}{dt}\left(\underbrace{\oint E\, dA}\right)$$

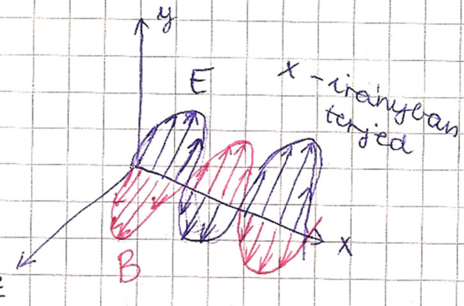
Gauss-törvény: $\frac{Q}{\varepsilon_0}$

$$I_d = \varepsilon_0 \cdot \frac{d}{dt} Q \cdot \frac{1}{\varepsilon_0} = \frac{dQ}{dt} = u \cdot C\left(-\frac{1}{RC}\right)\left(-e^{-\frac{t}{RC}}\right)$$

$$I_d = \frac{u}{R} \cdot e^{-\frac{t}{RC}} = 0{,}033\ A$$

35A - 10

$E \perp B$




E és B szinuszosan változik.

hullámegyenlet: $\frac{\partial E_y}{dx} = -\frac{\partial B_z}{dt}$ $\frac{E_y}{B_z} = c \rightarrow$ fénysebesség

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

a)

$E_0 = 25 \frac{V}{m}$

$c = 3 \cdot 10^8 \frac{m}{s}$

$B_0 = ?$

$\frac{E_0}{B_0} = c \Longrightarrow B_0 = 8{,}33 \cdot 10^{-8}\ T$

b) $\lambda = 2{,}8\ m$
$f = ?$

$c = \lambda \cdot f \Longrightarrow f = \frac{c}{\lambda} = 107\ MHz$

c) $E = E_0 \cdot \sin|kx - \omega t|$

$k = \frac{2\pi}{\lambda} = 2{,}24 \frac{1}{m}$ $\omega = c \cdot k = 6{,}73 \cdot 10^8 \frac{1}{s}$

$E = 25\,(2{,}24x - 6{,}73 \cdot 10^8 t)$

35B - 14

$d = 2\ mm$ rézhuzal

$\rho = 5{,}2\ m\Omega/m$

$I = 20A$ áram halad át

a) $E_0 = ?$ a huzal felületén?

$R = \rho \cdot l$

# 4. gyakorlat

2013.10.30.

Poynting - vektor:

- jele: $S$
- képlete: $S = \frac{1}{2\mu_0} E \times B$

időbeli átlag: $S_{átl} = \frac{1}{2\mu_0} E_0 \cdot B_0$ (Intenzitás)

$u_{átl} = \frac{1}{2}\varepsilon_0 E^2 \rightarrow$ elektromos tér energiája

$\parallel$

$\frac{1}{2\mu_0} B^2$

$$S_{átl} = u_{átl} \cdot c$$

nyomás $= \frac{S_{átl}}{c}$ (elnyelődéskor)

nyomás $= \frac{2 \cdot S_{átl}}{c}$ (visszaverődéskor)

35B - 25

$P = 15\,mW$ hélium-neon lézer
$d = 2\,mm$ (kör alakú nyaláb)
$\lambda = 632.8\,nm$

a) $E_0 = ?$

$u_{átl} = \frac{1}{2}\varepsilon_0 E_0^2$

$S_{átl} = \frac{P}{A} = \frac{P}{R^2 \pi} = \frac{15 \cdot 10^{-3}\,W}{\pi\,(10^{-3}\,m)^2} =$

$= 4774.65\,\frac{W}{m^2}$

$S_{átl} = u_{átl} \cdot c = \frac{1}{2}\varepsilon_0 c \cdot E_0^2 \Rightarrow E_0 = \sqrt{\frac{2 \cdot S_{átl}}{\varepsilon_0 \cdot c}} = 1896.5\,\frac{V}{m^2}$

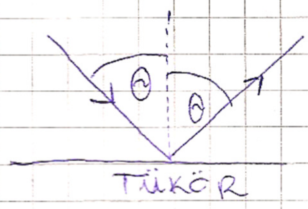
b) $E = ?$ $l = 1\,m$-es szakaszon

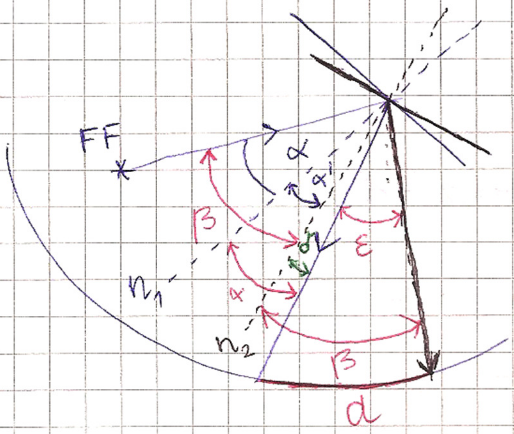
$E = u_{átl} \cdot V = \frac{S_{átl}}{c} \cdot V = \frac{S_{átl}}{c} \cdot A \cdot l = 5 \cdot 10^{-11}\,J$

c) $p = ?$ a nyaláb impulzusa

$E = c \cdot p \Rightarrow \quad p = \frac{E}{c} = 1.67 \cdot 10^{-19}\,\frac{kg \cdot m}{s}$

36A-2 GEOMETRIAI OPTIKA




$\alpha = 15°$ $R = 3m$ $d = ?$

Tükröt 2°-al elforgatjuk! → $\alpha' = 2°$

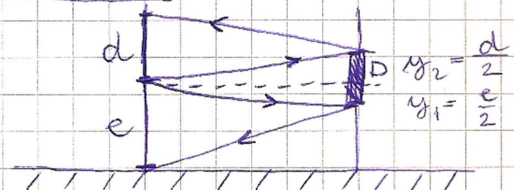
$\varepsilon = \beta - \delta$

$\delta = \alpha - \alpha'$

$$\frac{d}{2R\pi} = \frac{\varepsilon}{360°} \Longrightarrow d = \frac{\beta - (\alpha - \alpha')}{180°} R\pi = \frac{17° - (15° - 2°)}{180°} R\pi =$$

$= 0,209$ m

36B-4




$e = 1,59$ m

$d = 0,14$ m

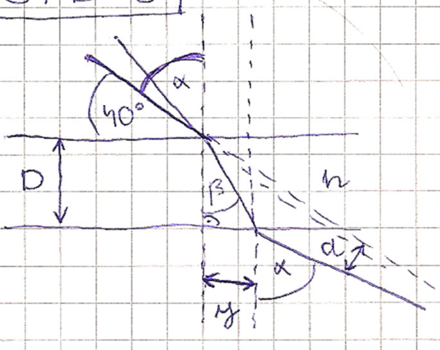
$h = y_1 + y_2 = \frac{e}{2} + \frac{d}{2} = 0.865$ m a padlótól $y_1$ távolságra van a tükör alja.

36B-13 $t = 5$ cm $N = 4$ $R = ?$

$$\frac{2}{R} = \frac{1}{f} = -\frac{1}{k} + \frac{1}{t}$$ $R = 8$ cm

nagyítás: $N = \frac{k}{t} \Longrightarrow k = N \cdot t$

37B-3




$D = 1,5$ cm
$n = 1,6$
$\alpha = 50°$

(I) $d = x \cdot \cos\alpha$

(II) $\frac{y}{D} = \mathrm{tg}\,\beta = \frac{\sin\beta}{\cos\beta}$

(III) $\frac{x+y}{D} = \mathrm{tg}\,\alpha$

(IV) $\frac{\sin\alpha}{\sin\beta} = n$

(II) $y = D \cdot \frac{1}{n} \sin\alpha \frac{1}{\underbrace{\sqrt{1 - \frac{\sin^2\alpha}{n^2}}}_{\substack{\cos\beta \\ (1-\sin^2\beta)}}} = D \cdot \frac{\sin\alpha}{\sqrt{n^2 - \sin^2\alpha}}$

(III) $x = D \cdot \text{tg}\,\alpha - y$

(I) $d = (D \cdot \text{tg}\,\alpha - y) \cos\alpha = \left( D \cdot \frac{\sin\alpha}{\cos\alpha} - y \right) \cdot \cos\alpha =$

$= D \sin\alpha - y \cdot$ ~~sin~~ $\cos\alpha$

$d = D \cdot \sin\alpha \left( 1 - \frac{\cos\alpha}{\sqrt{n^2 - \sin^2\alpha}} \right) = 1{,}5\ \text{cm} \cdot \sin 50 \left( 1 - \frac{\cos 50}{\sqrt{(1{,}6)^2 - (\sin 50)^2}} \right) =$

$= 0{,}62\ \text{m}$

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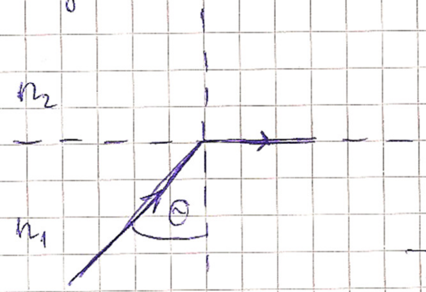
Teljes visszaverődés




határ eset

$\sin\Theta$

$\frac{1}{f} = (n-1)\left( \frac{1}{R_1} + \frac{1}{R_2} \right)$

# 5. gyakorlat

2013. 11. 13.

Lorentz-transzformáció:

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad x = \frac{x' + vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

vesszős a mozgó, vessző nélküli a sima

**41A-3**

$t'_0 = 2$ min (űrhajós koord. rendszerében)

a) $v = 0{,}5c$ (földhöz képest)

$$t = \frac{t' + \frac{v x'}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad x' = 0 \implies t = \frac{t'}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{2\,\text{min}}{\sqrt{1 - \frac{(0{,}5c)^2}{c^2}}} =$$

$= 2{,}31$ min

↑ földi idő

b) $x = ?$

$$x = \frac{x' - vt'}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad x' = 0 \implies x = 1{,}15c \text{ (min)}$$

↑ c egységekben kifejezve

**41B-7**

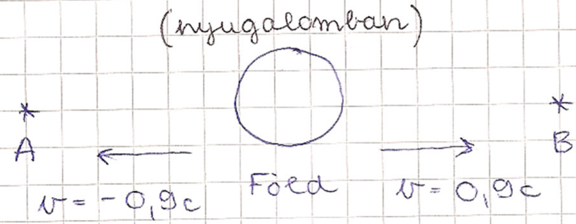
$v = 0{,}8c$
$x = 30$ m } részecske fele elbomlik

→ felezési idő $t = \frac{x}{v} = 37{,}5\,\frac{1}{c}$

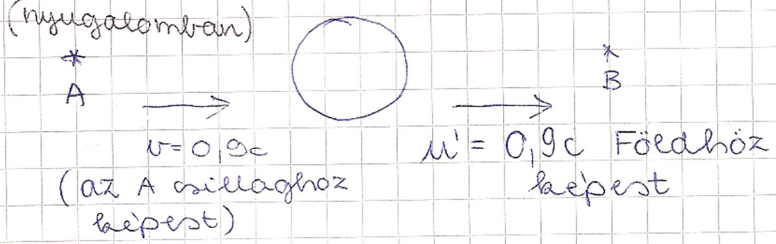
részecske vonatkoztatási rendszerében:

$$t' = \frac{t - \frac{v}{c^2}x}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{13{,}5\,\frac{1}{c}}{0{,}6} = 22{,}5\,\frac{1}{c}$$

## 41A-15








$u = ?$ az A galaxishoz képest

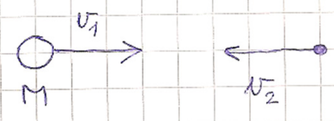
$$u = \frac{x}{t} = \frac{\frac{x' + vt'}{\sqrt{1 - \frac{v^2}{c^2}}}}{\frac{t' + v\frac{x'}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}} = \frac{x' + vt}{t' + v\frac{x'}{c^2}}$$

$$u = \frac{t'(u' + v)}{t'\left(1 + \frac{vu'}{c^2}\right)} = \frac{u' + v}{1 + \frac{v \cdot u'}{c^2}} \Longrightarrow$$ relativisztikus sebességösszeadás

$$u = 0,9945c$$

## 41B-17

$M \to v_1 = 0,6c$
$m \to v_2 = 0,8c$




u.u → nyugalomba kerülnek

$P_1 + P_2 = \varnothing$

$\frac{M}{m} = ?$

$$P_1 = \frac{M v_1}{\sqrt{1 - \frac{v_1^2}{c^2}}} \qquad P_2 = -\frac{m \cdot v_2}{\sqrt{1 - \frac{v_2^2}{c^2}}}$$

$$P_1 = \frac{0,6}{0,8} Mc = \frac{3}{4} Mc \qquad P_2 = -\frac{4}{3} mc$$

$P_1 + P_2 = 0$

$$\frac{3}{4} M = \frac{4}{3} m \Longrightarrow \frac{M}{m} = \frac{16}{9} = 1,78$$

$$\boxed{E = m \cdot c^2}$$

↑ nyugalmi energia

41B-26

a) $v = 0{,}8c$

klasszikusan: $W = \frac{1}{2}mv^2 = \frac{1}{2}m(0{,}8c)^2 = 0{,}32\ mc^2$

b) relativisztikusan:

$$W = \frac{m \cdot c^2}{\sqrt{1-\frac{v^2}{c^2}}} - mc^2 = mc^2\left(\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right) = 0{,}67\ mc^2$$