EREMU GRABITATORIOA

- INDAR GRABITATORIOA: $\boxed{|\vec{F}| = G\frac{M_1 \cdot m_2}{d^2}}$ (N) $\rightarrow$ $\boxed{\vec{F} = m_2 \cdot \vec{g}}$

- EREMUAREN INTENTSITATE BEKTOREA EDO AZELERAZIOA $\boxed{|\vec{g}| = G\frac{M_1}{d^2}}$ $\left(\frac{N}{Kg} \text{ edo } \frac{m}{s^2}\right)$

- EREMUKO PUNTU BATEKO ENERGIA POTENTZIALA: $\boxed{E_p = -G\frac{M_1 \cdot m_2}{d}}$ (J) $\rightarrow$ $\boxed{E_p = m_2 \cdot V}$

- EREMUKO PUNTU BATEKO POTENTZIAL GRABITATORIOA: $\boxed{V = -G\frac{M_1}{d}}$ $\left(\frac{J}{Kg}\right)$

- EREMUAK EGINDAKO LANA: $\boxed{W_{EREMUA} = -\Delta E_p}$

- ABIADURA ORBITALA: ... $|\vec{F_2}| = |\vec{F_G}|$ ... $\boxed{v_{ORB} = \sqrt{G\frac{M_1}{d}}}$ $\left(\frac{m}{s}\right)$

- IHES ABIADURA: ... $E_{m_A} = E_{m_\infty}$ .... $\boxed{v_i = \sqrt{2G\frac{M_1}{d}}}$ $\left(\frac{m}{s}\right)$

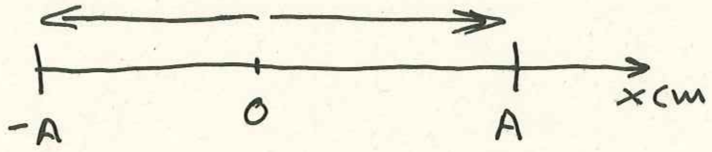
- ORBITAN EGONDA: E_m .... $\boxed{E_m = \frac{1}{2}E_p}$ eta $\boxed{E_z = \frac{1}{2}|E_p|}$

- KEPLERREN 3. LEGEA: $\boxed{\frac{T^2}{R^3} = kte}$ $\frac{T_A^2}{R_A^3} = \frac{T_B^2}{R_B^3} = \dots = \frac{T_n^2}{R_n^3}$

- ABIADURA ANGELUARRA $\omega = \frac{\text{angelua}}{\text{denpora}}$ $\boxed{\omega = \frac{2\pi}{T}}$ $\left(\frac{rad}{s}\right)$

eta $\boxed{v = \omega \cdot R}$

HHS (HIGIDURA HARMONIKO SINPLEA)



- ELONGAZIOA: $\boxed{x(t) = A\sin(\omega t + \varphi_0)}$ (m)
- ABIADURA: $\boxed{v(t) = \frac{dx(t)}{dt}} = A\omega\cos(\omega t + \varphi_0)$ (m/s)
- AZELERAZIOA: $\boxed{a(t) = \frac{dv(t)}{dt}} = -A\omega^2\sin(\omega t + \varphi_0)$ (m/s^2)

  $\hookrightarrow$ edo $\hookrightarrow$ $a(t) = -\omega^2 x(t)$

- PULTSAZIOA: $\boxed{\omega = \frac{2\pi}{T} = 2\pi \cdot f}$ (rad/s) $\boxed{T = 1/f}$

  PERIODOA: T (s) ; MAIZTASUNA EDO FREKUENTZIA: f (s^{-1} edo Hz)

- $\left\{ \begin{array}{l} \text{Hooke: } F = -K\cdot x \\ \text{Nw. 2.L: } F = m\cdot a \underset{a=-\omega^2 x}{=} -m\omega^2 x \end{array} \right\} \rightarrow (=)$ $\boxed{K = m\cdot\omega^2}$ $\longrightarrow$

PERIODOA ⟶ OSZILADORE HARMONIKO SINPLEAREN PERIODOA ⟶

$\rightarrow K = m\cdot\frac{2^2\pi^2}{T^2} \dots \rightarrow T = 2\pi\sqrt{\frac{m}{K}}$

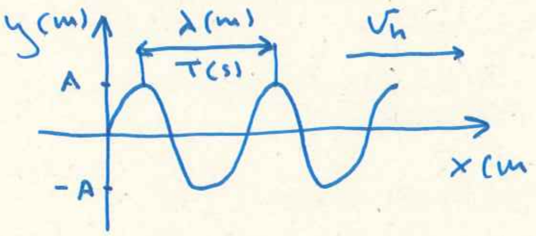
$\rightarrow$ Pendulo sinplean $T = 2\pi\sqrt{\frac{L}{g}}$

- ENERGIA MEKANIKOA (Kte)

$E_m = E_p + E_z$ $\boxed{E_p = \frac{1}{2}Kx^2}$ $E_z = \frac{1}{2}mv^2$

Muturrean $v = 0$ eta $x = A$. Geldirik $\Rightarrow E_m = E_{p_A} = \frac{1}{2}KA^2$

UHIN HARMONIKO SINPLEAK



UHIN FUNTZIOA

$$\boxed{y(x,t) = A\sin(\omega t - kx + \varphi_0)}$$ (m edo cm)

↑ AURRERA (ATZERA +)

- PULTSAZIOA EDO MAIZTASUN ANGELUARRA $\omega = \frac{2\pi}{T}$ edo $\omega = 2\pi \cdot f$ (rad/s)
- UHIN KOPURUA EDO UHIN ZENBAKIA $k = \frac{2\pi}{\lambda}$ (rad/m)
- HEDAPEN ABIADURA : $\boxed{v_h = \frac{\lambda}{T}}$ (m/s)
- BIBRAZIO ABIADURA: $v(x,t) = \frac{dy(x,t)}{dt} = \ldots = A\omega\cos(\quad)$

  $v_{max} \longrightarrow \cos = \pm 1 \longrightarrow v_{max} = \pm A\omega$
- BIBRAZIO AZELERAZIOA: $a(x,t) = \frac{dv(x,t)}{dt} = -A\omega^2\sin(\quad)$

  $a_{max} \longrightarrow \sin = \pm 1 \longrightarrow a_{max} = \pm A\omega^2$

—o—

POTENTZIA ⇒ $P = \frac{E}{t}$ $\left(\text{wat} = \frac{J}{s}\right)$

INTENTSITATEA = $\frac{\text{Potentzia}}{\text{azalera}}$ → $I = \frac{P}{S} \xrightarrow{\text{esferak}} I = \frac{P}{4\pi R^2}$ $\left(\frac{\text{wat}}{m^2}\right)$

—o—

DESFASEAK

FASEA SIN BARRUKOA DA : $(\omega t - kx + \varphi_0)$

KASUAK:

→ $x_1 = 3$ m eta $x_2 = 5$m-ko partikulen arteko desfasea:

$$\Delta\varphi_{3,5} = \varphi_3 - \varphi_5 = (\omega t - k\cdot 3 + \varphi_0) - (\omega t - k\cdot 5 + \varphi_0) = 2k \text{ (rad)}$$

→ Zeintzuen artean desfasea $\pi/3$ da?

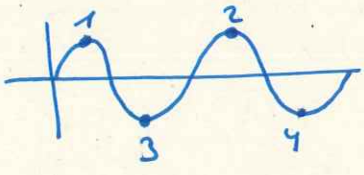
$$\varphi_x - \varphi_{x+d} = \pi/3 \longrightarrow (\omega t - kx + \varphi_0) - [\omega t - k(x+d) + \varphi_0] = \pi/3 \longrightarrow \ldots d$$

→ Zeintzuk fasean $x = 2$m-koaz? ⇒ FASEAN: $\Delta\varphi = n\cdot 2\pi$ $(n = \pm 1, \pm 2 ..)$

$$\varphi_2 - \varphi_{x_n} = n\cdot 2\pi \longrightarrow (\omega t - k\cdot 2 + \varphi_0) - [\omega t - k\cdot x_n + \varphi_0] = n\cdot 2\pi \rightarrow x_n$$

→ Zeintzuk kontrafasean? ⇒ KONTRAFASEA $\Delta\varphi = (2n+1)\pi$ $(n = 0, \pm 1, \pm 2 ..)$

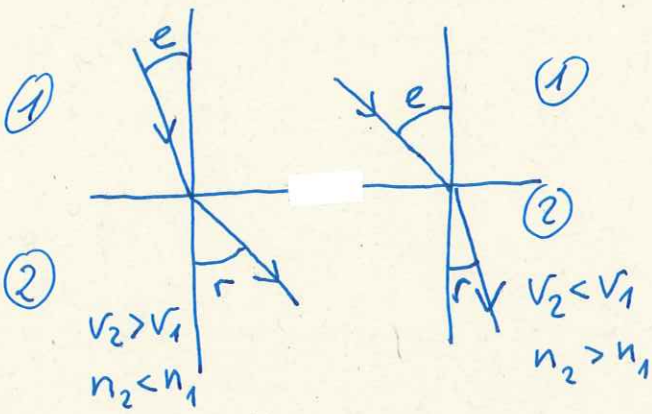
(Garapena berdin)



1-2 ⇒ FASEAN

1-3,4 ⇒ KONTRAFASEAN

ERREFRAKZIOA



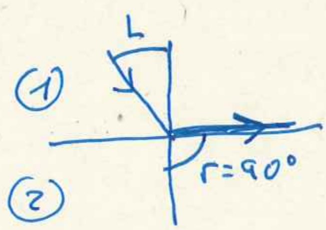
$\boxed{f \text{ ez da aldatzen}}$

$\boxed{v_i = \lambda_i \cdot f}$ $\boxed{c = 3 \cdot 10^8 \, m/s}$

- ERREFRAKZIO-INDIZEAK:
  - ABSOLUTUA $n_i = c / v_i$
  - ERLATIBOA $n_{21} = v_1 / v_2$

- SNELL-EN ERREFRAKZIOAREN LEGEA

$$\boxed{\frac{\sin e}{\sin r} = \frac{v_1}{v_2} = \frac{n_2}{n_1}} = n_{21}$$



- ISLAPEN OSOA $\longrightarrow$ BALDINTZA $v_2 > v_1$

$$\frac{\sin e}{\sin r} = \frac{v_1}{v_2} \xrightarrow[r=90°]{e=L} \sin L = \frac{v_1}{v_2} \longrightarrow L = \arcsin(v_1/v_2) = \arcsin(n_2/n_1)$$

UHIN ELEKTROMAGNETIKOAK

$$E(x,t) = E_0 \sin(\omega t - kx + \varphi_0)$$

$$B(x,t) = B_0 \sin(\omega t - kx + \varphi_0)$$

Eta beti: $\boxed{\frac{E}{B} = c}$

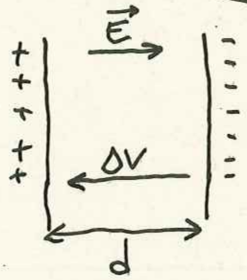
Uhin arruntak bezala lantzen dira. Biak erlazionatzeko edozein momentutan $\frac{E}{B} = c$ betetzen da.

(Hau selektibitaterako. Kurtsoan ez dot galdetzen)

EREMU ELEKTRIKOA

- INDAR ELEKTRIKOA: $\boxed{|\vec{F}| = K\dfrac{|Q_1|\cdot|Q_2|}{d^2}\ (N)}$ $\rightarrow \vec{F} = \vec{E}\cdot Q_2$
- EREMU ELEKTRIKOAREN INTENTSITATE BEKTOREA: $\boxed{|\vec{E}| = K\dfrac{|Q_1|}{d^2}\left(\dfrac{N}{C}\right)}$ $\nearrow \vec{F} = \vec{E}\cdot Q_2$
- ENERGIA POTENTZIALA: $\boxed{E_p = K\dfrac{Q_1\cdot Q_2}{d}\ (J)}$ $\rightarrow E_p = V\cdot Q_2$
- POTENTZIAL ELEKTROSTATIKOA: $\boxed{V = K\dfrac{Q_1}{d}\left(\dfrac{J}{C}\text{ edo } V\right)}$ $\nearrow E_p = V\cdot Q_2$

$\oplus \xrightarrow{\vec{E}} \ominus$;



$\boxed{|\vec{E}|\cdot d = \Delta V}$

$\hookrightarrow$ ($\vec{E}$ bebai $\frac{V}{m}$)

- EREMU ELEKTRIKOAK EGINDAKO LANA: $\boxed{W_{EREM} = -\Delta E_p}$

- ENERGIEN BALANTZEAK:
  - Eremua zentrala da, beraz kontserbakorra, holan $E_m = kte \rightarrow$

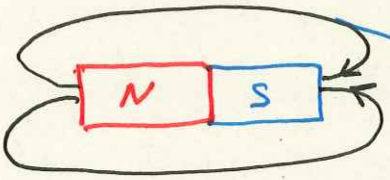
$\rightarrow E_{mA} = E_{mB} \rightarrow E_{zA} + E_{pA} = E_{zB} + E_{pB} \rightarrow$

$\rightarrow \frac{1}{2}m_2 v_A^2 + Q_2\cdot V_A = \frac{1}{2}m_2 v_B^2 + Q_2\cdot V_B \rightarrow$

$\rightarrow \frac{1}{2}m_2 v_A^2 - \frac{1}{2}m_2\cdot v_B^2 = \underline{Q_2\cdot\Delta V}$

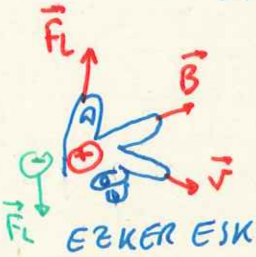
Hortik joango gara, ez Ep konkretuak kalkulatzen (orokorrean)

EREMU MAGNETIKOA



$\vec{B}$: indukzio bektorea (T, Tesla)

- KARGA BATEN GAINEKO INDAR MAGNETIKOA
  - LORENTZEN INDARRA: $\boxed{\vec{F}_L = q\cdot(\vec{v}\wedge\vec{B})} = q\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix}$



$\vec{v}\perp\vec{B} \Rightarrow$ ibilbide zirkularra $\Rightarrow \vec{F}_L \equiv \vec{F}_z \rightarrow$

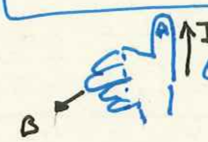
$\rightarrow \quad q\,v\,B\sin\underset{90^\circ}{\alpha} = m\dfrac{v^2}{R} \rightarrow R$ lortu $\rightarrow$ denpora $\rightarrow$

$\rightarrow v = \dfrac{2\pi}{T}\cdot R \rightarrow T$ lortu

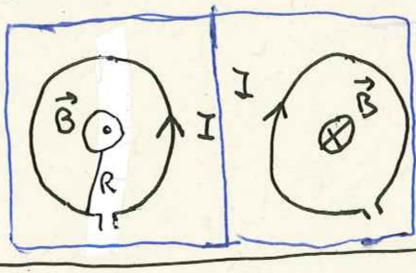
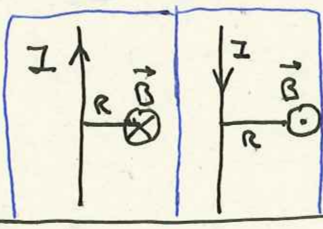
- KORRONTE ELEMENTU BATEN GAINEKO INDAR MAGNETIKOA:

$$\vec{F}_L = q\,(\vec{v}\times\vec{B}) = q\left(\frac{\vec{l}}{\Delta t}\times\vec{B}\right) = \frac{q}{\Delta t}(\vec{l}\times\vec{B}) \Rightarrow \boxed{\vec{F}_L = I\cdot(\vec{l}\times\vec{B})}$$

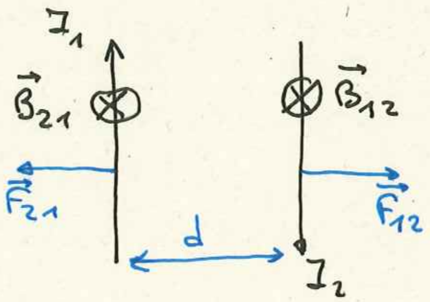
- KORRONTE BATEK SORTURIKO EREMU MAGNETIKOA



BIOT-SAVART LEGEA

ESPIRA BATEN ERDIAN	KORRONTE ZUZEN INFINITUAK R DISTANTZIARA
 $B = \dfrac{\mu_0 I}{2R}$	 $B = \dfrac{\mu_0 I}{2\pi R}$

- BI KABLEEN ARTEKO ALKARREKINTZA

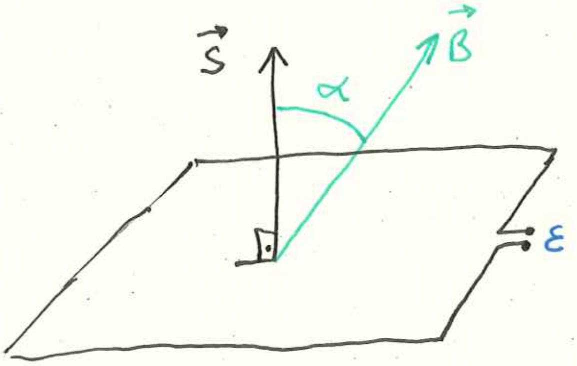


$B_{12} = \dfrac{\mu_0 I_1}{2\pi d} \rightarrow F_{12} = I_2\cdot l_2\cdot B_{12} = \dfrac{I_2 l_2 \mu_0 I_1}{2\pi d}$

$B_{21} = \dfrac{\mu_0 I_2}{2\pi d} \rightarrow F_{21} = I_1\cdot l_1 B_{21} = \dfrac{I_1 l_1 \mu_0 I_2}{2\pi d}$

Edo l_1 eta l_2 emoten deuskue, edo bestela 1m jarri eta indarraren emoitza, adibidez: $8\,\dfrac{N}{m}$

INDUKZIO ELEKTROMAGNETIKOA



- FLUXU MAGNETIKOA: ϕ

$$\boxed{\phi = \vec{B} \cdot \vec{S} = B \cdot S \cdot \cos\alpha} \quad (Wb)$$

S = azalera: $S = a \times b$ (m^2); $S = \pi R^2$ (m^2)

- INDAR ELEKTROERAGILE INDUZITUA: ε (V)

⇒ FARADAY-REN LEGEA

TARTEKA: $\boxed{\varepsilon = -\dfrac{\Delta \phi}{\Delta t}}$ (V)

JARRAIA: $\boxed{\varepsilon(t) = -\dfrac{d\phi(t)}{dt}}$ (V)

⇐ MINUSA EZINBESTEKOA LENZ-ERI JARRAITUZ

- KANPOKO ZIRKUITO BATERI ε-ek HORNITUTAKO KORRONTEA (I) ZIRKUITUAN, R (Ω) ERRESISTENTZIA EGONDA ⇒

⇒ OHM-EN LEGEA

$$\boxed{I = \frac{\varepsilon}{R}} \quad (A)$$

$\vec{B}$: indukzio bektorea (T; Tesla)

ϕ: fluxu magnetikoa (Wb; Weber)

$\vec{S}$: azalera bektorea (m^2)

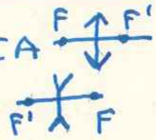
ε: indar elektroeragile induzitua (V; volt)

R: erresistentzia (Ω; ohm)

I: intentsitatea (A; ampere)

OPTIKA GEOMETRIKOA

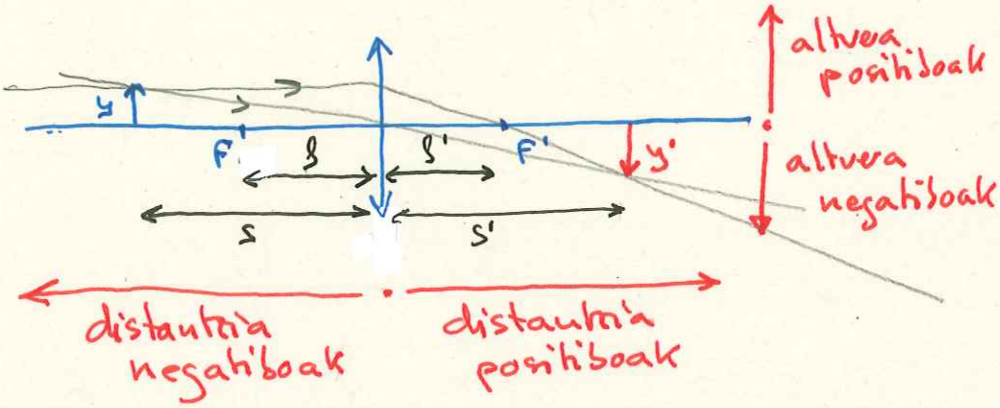
LEIAR MEHEAK (LENTE MEHEAK): KONBERGENTEA
DIBERGENTEA



$$\boxed{\frac{1}{s'}-\frac{1}{s}=\frac{1}{f'}}=\frac{-1}{f}$$

Emendioa:

$$\boxed{\frac{y'}{y}=\frac{s'}{s}}$$



Potentzia (dioptriak):

$$\boxed{P=\frac{1}{|f|}}$$ dioptriak

s: objektu-distantzia

s': irudi-distantzia

f: objektu distantzia fokala

f': irudi distantzia fokala

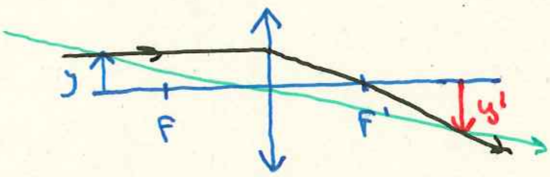
$|f|=|f'|=\frac{R}{2}$ (R: lentearen kurbadura erradioa)

F: objektu fokua

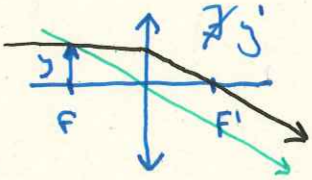
F': irudi fokua

y: objektuaren tamaina

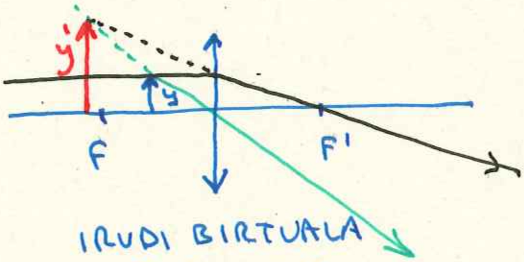
y': irudiaren tamaina



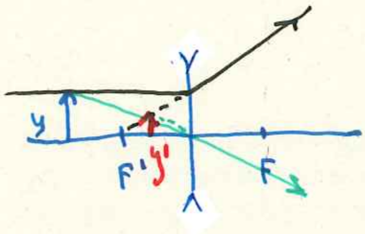
IRUDI ERREALA ALDERNTZIZ

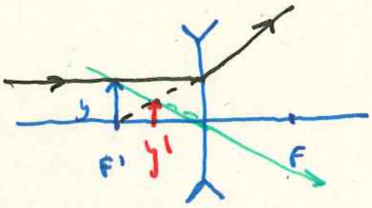


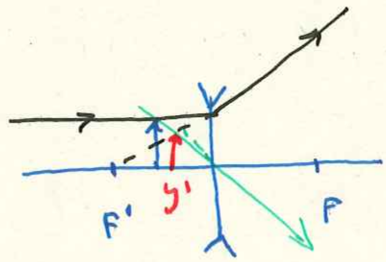
$\nexists$ IRUDIRIK



IRUDI BIRTUALA ETA ZUZENA







DIBERGENTEETAN IRUDIA BETI:
- BIRTUALA
- ZUZENA
- OBJEKTUA BAINO TXIKIAGOA

Dioptrio esferikoaren oinarrizko ekuazioa:

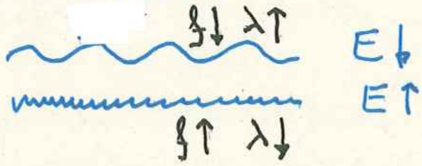
$$\boxed{\frac{n'}{s'}-\frac{n}{s}=\frac{n'-n}{R}}\qquad M_L=\frac{y'}{y}=\frac{ns'}{n's}\qquad f=\frac{R}{2}$$

Ispiluetan: $n'=-n$; lauetan $R=\infty$

EFEKTU FOTOELEKTRIKOA

- PLANCK: Uhinak energia paketetan dakar.

  Pakete, fotoi edo kuantum bakotxaren energia: $\boxed{E = h \cdot f}$



- EINSTEINEN INTERPRETAZIOA:

$$\boxed{E = W_0 + E_{z\,max}}$$

W_0 (erauzketa lana)

- ATARI MAIZTASUNA $f_u \Rightarrow W_0$ (lotura apurtzeko energia dakar)

(edo $\lambda < \lambda_u$) $\rightarrow$ $f < f_u \Rightarrow \nexists$ fotoelektroirik

(edo $\lambda > \lambda_u$) $\rightarrow$ $f > f_u \Rightarrow \exists$ fotoelektroiak.

- BALAZTATZE POTENTZIALA.

  Fotoelektroien soberako E_z anulatzeko potentziala, beraz:

$$E_z = q V_B \rightarrow \frac{1}{2} m v^2 = q \cdot V_B \quad \text{(edo } V_{stop}\text{)}$$