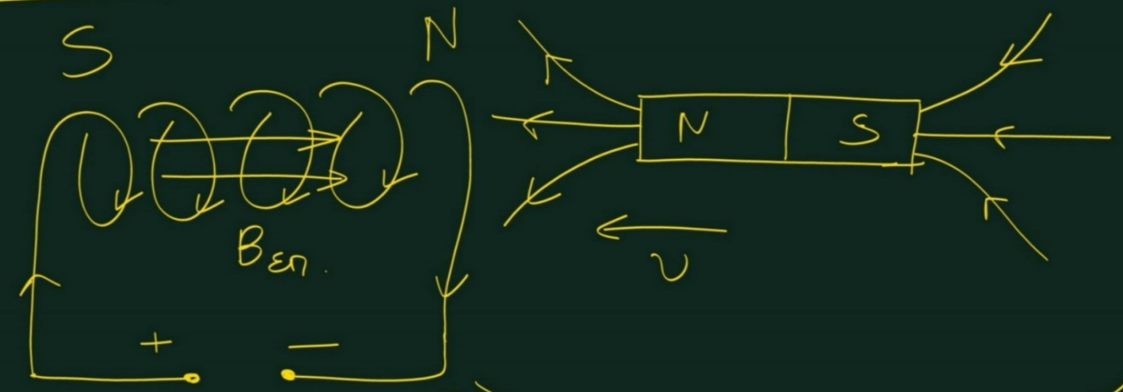
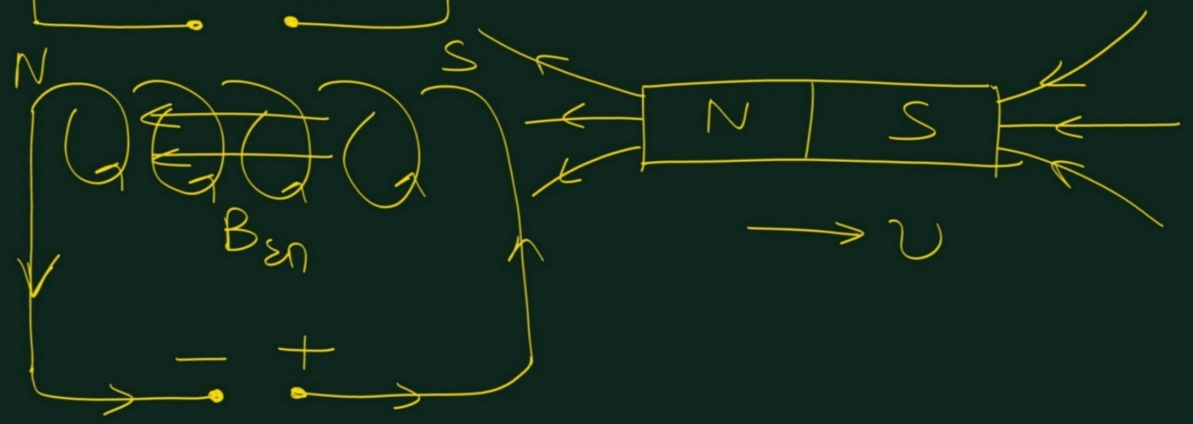
Biot-Savarizm.





$$E_{ind} = N \frac{|\Delta \Phi|}{\Delta t} \Rightarrow$$

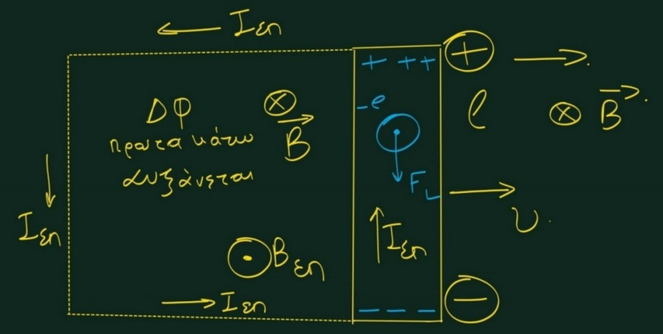
$$I_{ind} \cdot R_{ob} = N \cdot \frac{|\Delta \Phi|}{\Delta t} \Rightarrow$$

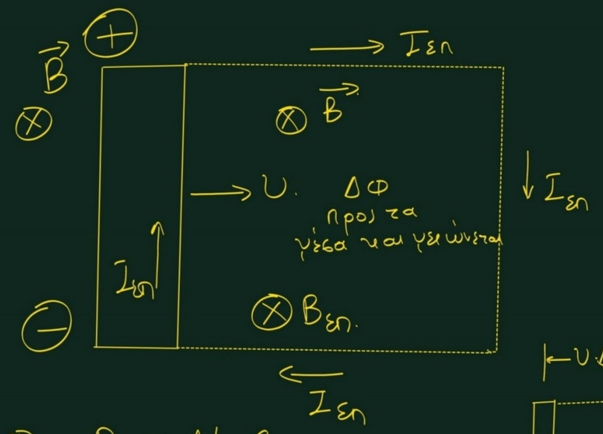
$$\frac{\Delta Q}{\Delta t} \cdot R_{ob} = N \cdot \frac{|\Delta \Phi|}{\Delta t} \Rightarrow$$

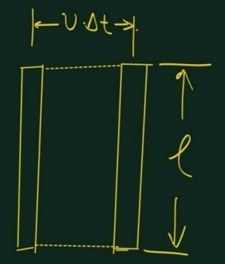
$$\Delta Q = N \cdot \frac{|\Delta \Phi|}{R_{ob}}$$

Franz Neumann.

Ευθύγραμμος αγωγός σε ομογενές μαγνητικό πεδίο.







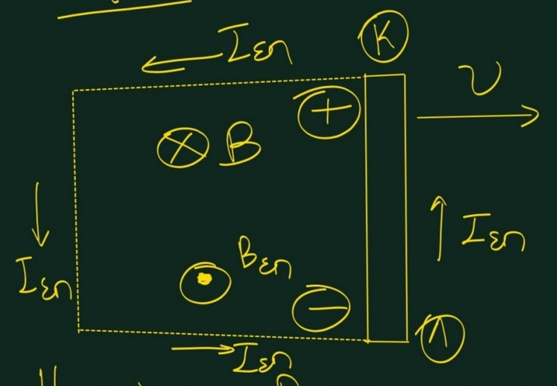
Η ροή του μαγνητικού πεδίου στο αριστερό υποθετικό κύκλωμα είναι προς τα κάτω και αυξάνεται.

$$\Delta\Phi = B\cdot\upsilon\cdot\Delta t\cdot\ell$$

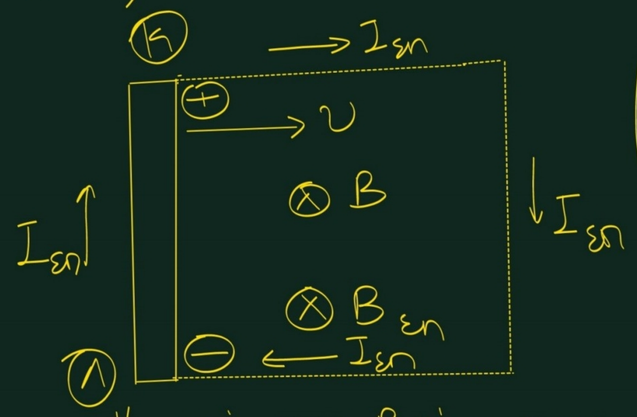
$$\mathcal{E}_{\varepsilon\pi} = \frac{\Delta\Phi}{\Delta t} = \frac{B\cdot\upsilon\cdot\Delta t\cdot\ell}{\Delta t} = B\upsilon\ell$$

Υπάρχουν δύο τρόποι εύρεσης της πολικότητας του αγωγού

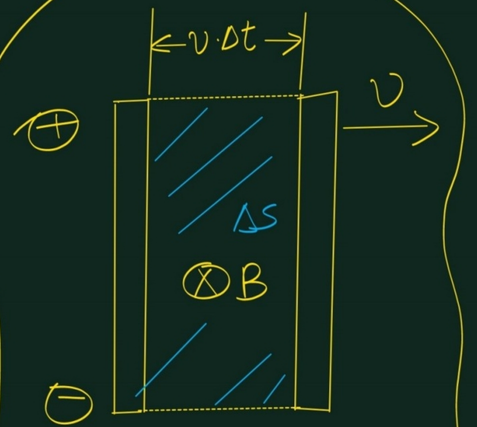
1ο τρόπος (Μακροσκοπικά, κανόνας Lentz)



Η ροή του B είναι προς τα μέσα και αυξάνεται άρα το $B_{επ}$ είναι προς τα έξω.



Η ροή του B είναι προς τα μέσα και μειώνεται, άρα το $B_{επ}$ έχει φορά προς τα μέσα.

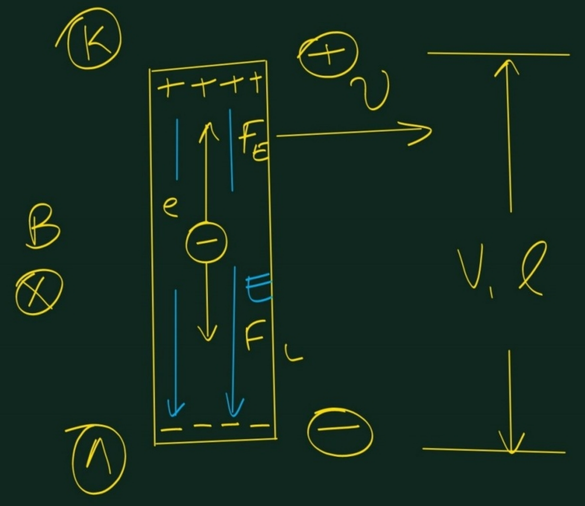


Σε χρόνο Δt ο αγωγός σαρώνει επιφάνεια

$$\Delta S = \upsilon \cdot \Delta t \cdot \ell$$

Άρα: $E_{επ} = \frac{\Delta \Phi}{\Delta t} = \frac{B \cdot \Delta S}{\Delta t} \Rightarrow$ *

2ος τρόπος (γιατί προκύπτει από τη δύναμη Lorentz).



$$F_E = F_L \Rightarrow$$

$$\cancel{e} E = \cancel{e} \upsilon B \Rightarrow$$

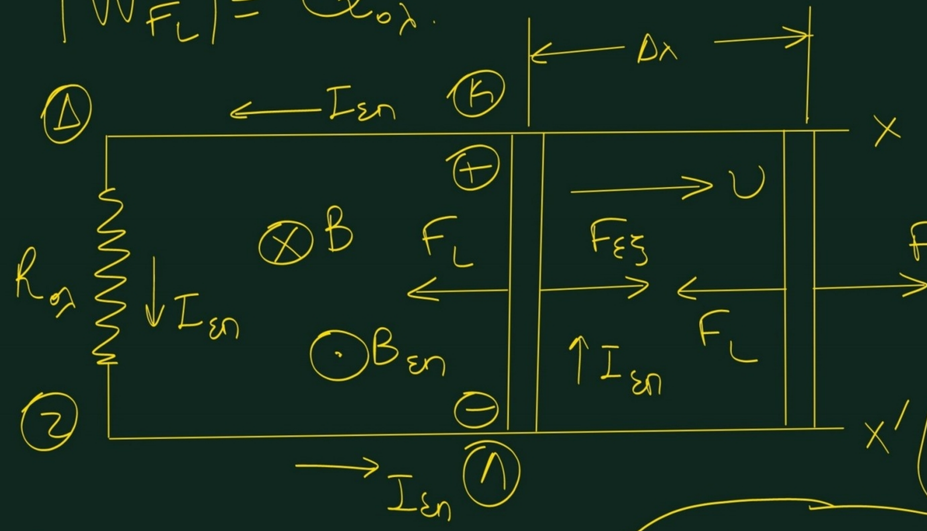
$$\frac{V}{\ell} = \upsilon B \Rightarrow V = B\upsilon\ell$$

ή $E_{\varepsilon\pi} = B\upsilon\ell$.

$$* \quad E_{\varepsilon\pi} = \frac{B \cdot \upsilon \cdot \Delta t \cdot \ell}{\Delta t} \Rightarrow E_{\varepsilon\pi} = B\upsilon\ell$$

Διατήρηση ενέργειας:

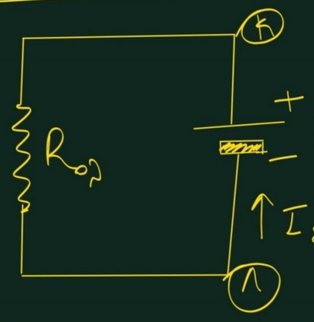
$$|W_{F_L}| = Q_{ολ}.$$



$R_{ολ}$ = ολική ισοδύναμη αντίσταση του κυκλώματος

$$|W_{F_L}| = F_L \cdot \Delta x = B I_{επ} \ell \cdot \Delta x = B \frac{B\upsilon\ell}{R_{ολ}} \cdot \Delta x = \frac{B^2 \upsilon \ell^2}{R_{ολ}} \cdot \Delta x$$

Ισοδύναμο κύκλωμα



$$Q_{ολ} = I_{επ}^2 R_{ολ} \Delta t = \frac{E_{επ}^2}{R_{ολ}^2} \cdot R_{ολ} \Delta t = \frac{B^2 \upsilon^2 \ell^2}{R_{ολ}} \cdot \Delta t = \frac{B^2 \upsilon \ell^2}{R_{ολ}} \cdot \upsilon \Delta t = \frac{B^2 \upsilon \ell^2}{R_{ολ}} \cdot \Delta x.$$

Ασκ. 5.58. σελ. 223

$r = 8\,cm$

N σπείρες

$S = 0{,}1\,cm^2$

$B = 2 \cdot 10^{-5}\,T$

$\rho = 1{,}6 \cdot 10^{-6}\,\Omega \cdot cm$

Θέλουμε το φορτίο από μία διατομή του σύρματος.

$\Delta Q =$ φορτίο.

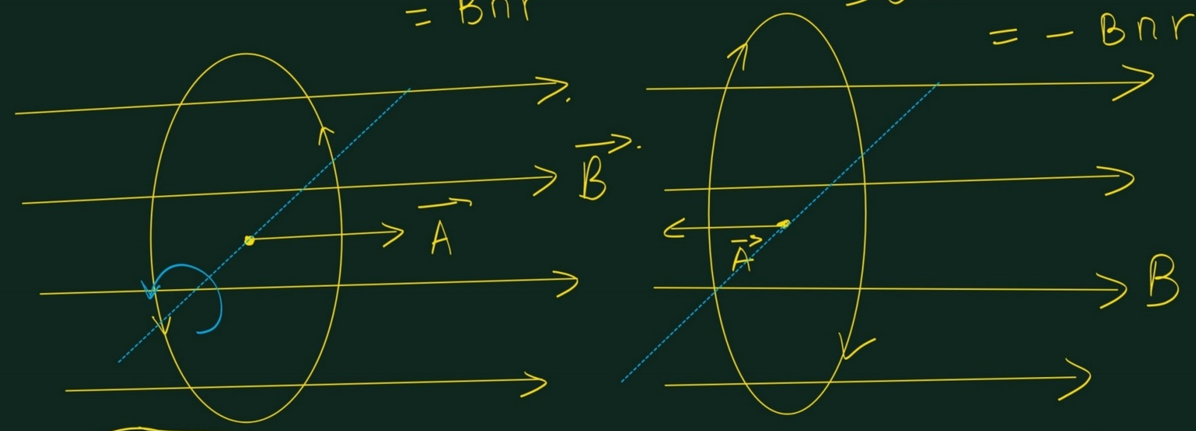
$\Phi_{αρχ} = \vec{B} \cdot \vec{A} = B \cdot \pi r^2 \cdot \sigma\upsilon\nu 0^\circ =$

$= B \pi r^2$

$\Phi_{τελ} = \vec{B} \cdot \vec{A} =$

$= B \cdot \pi r^2 \cdot \sigma\upsilon\nu 180^\circ =$

$= -B \pi r^2$



$A = \pi r^2$

$\ell = 2\pi r \cdot N$

$E_{επ} = N \cdot \frac{|\Delta\Phi|}{\Delta t} \Rightarrow I_{επ} \cdot R_\pi = N \cdot \frac{|\Delta\Phi|}{\Delta t} \Rightarrow$

$\frac{\Delta Q}{\cancel{\Delta t}} \cdot R_\pi = N \cdot \frac{|\Phi_{τελ} - \Phi_{αρχ}|}{\cancel{\Delta t}} \Rightarrow \Delta Q = \frac{N \cdot |-B\pi r^2 - B\pi r^2|}{R_\pi}$

$$\Delta Q = \frac{N \cdot 2B\pi r^2}{R_n} =$$

$$= \frac{N \cdot 2B\pi r^2}{\rho \cdot \frac{l}{S}} = \frac{2B\pi r^2 \cdot \cancel{N}}{\rho \cdot \frac{2\pi r \cdot \cancel{N}}{S}} \Rightarrow$$

$$\Delta Q = \frac{B r \cdot S}{\rho} = \frac{2 \cdot 10^{-5} \cdot 8 \cdot 10^{-2} \cdot 0{,}1 \cdot 10^{-4}}{1{,}6 \cdot 10^{-6} \cdot 10^{-2}} \Rightarrow$$

$$\Delta Q = \frac{1{,}6 \cdot 10^{-11}}{1{,}6 \cdot 10^{-6} \cdot 10^{-2}} \Rightarrow \Delta Q = 10^{-3}\ C.$$

$r = 8\ cm = 8 \cdot 10^{-2}\ m$

$S = 0{,}1\ cm^2 = 0{,}1 \cdot 10^{-4}\ m^2$

$\rho = 1{,}6 \cdot 10^{-6}\ \Omega \cdot cm \Rightarrow$

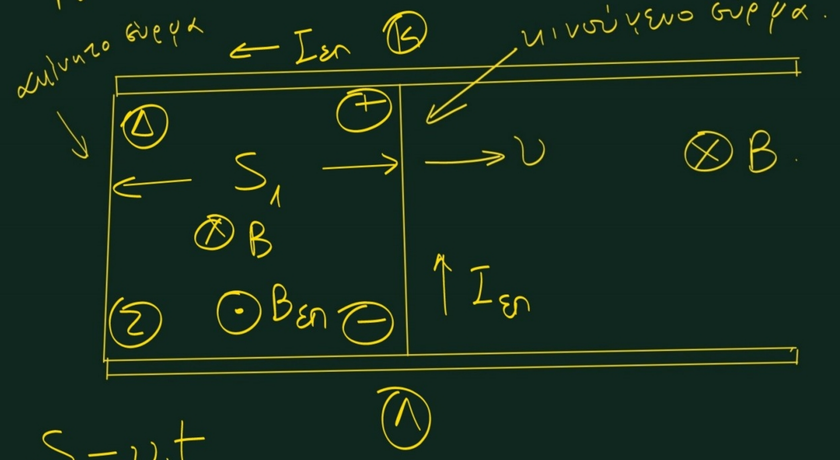
$\rho = 1{,}6 \cdot 10^{-8}\ \Omega \cdot m$

Ασκ. 5.59. σελ. 223.

$B = 5 \cdot 10^{-2}\ T$

$l = 10\ cm$

$R^* = 0{,}01\ \Omega/cm$



$S_1 = \upsilon \cdot t$

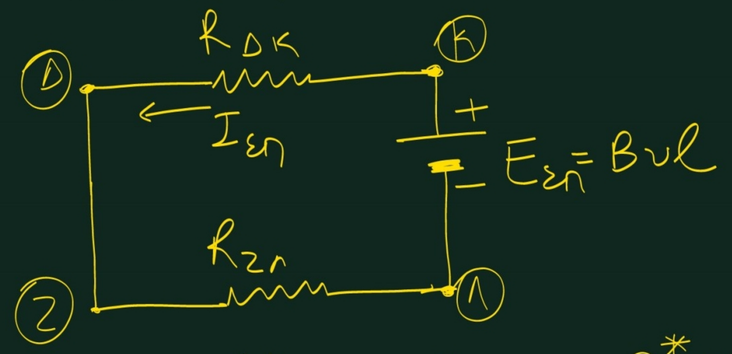
Ο αγωγός ΚΛ, τη στιγμή $t=0$ βρίσκεται στη θέση ΔΣ.

Άρα: $S_1 = \upsilon \cdot t$

α) $I_{επ} = \dfrac{E_{επ}}{R_{ολ}}$

$R_{ολ} = R_{ΔΚ} + R_{ΣΛ}$

Ισοδύναμο κύκλωμα:



$R_{ΔΚ} = \rho \cdot \dfrac{ΔΚ}{S} = \dfrac{\rho}{S} \cdot S_1 = R^* \cdot S_1 = R^* \cdot \upsilon \cdot t$

$R_{ΣΛ} = \rho \cdot \dfrac{ΣΛ}{S} = R^* \cdot \upsilon \cdot t$

Apa: $I_{\varepsilon n} = \dfrac{B \cdot l}{2 R^* v \cdot t} \Rightarrow$

$$I_{\varepsilon n}(t) = \frac{B\,l}{2R^* \cdot t} = \frac{5 \cdot 10^{-2} \cdot 10 \cdot 10^{-2}}{2 \cdot 1 \cdot t} = \frac{2{,}5 \cdot 10^{-3}}{t}$$

$R^* = 0{,}01\ \Omega/cm =$

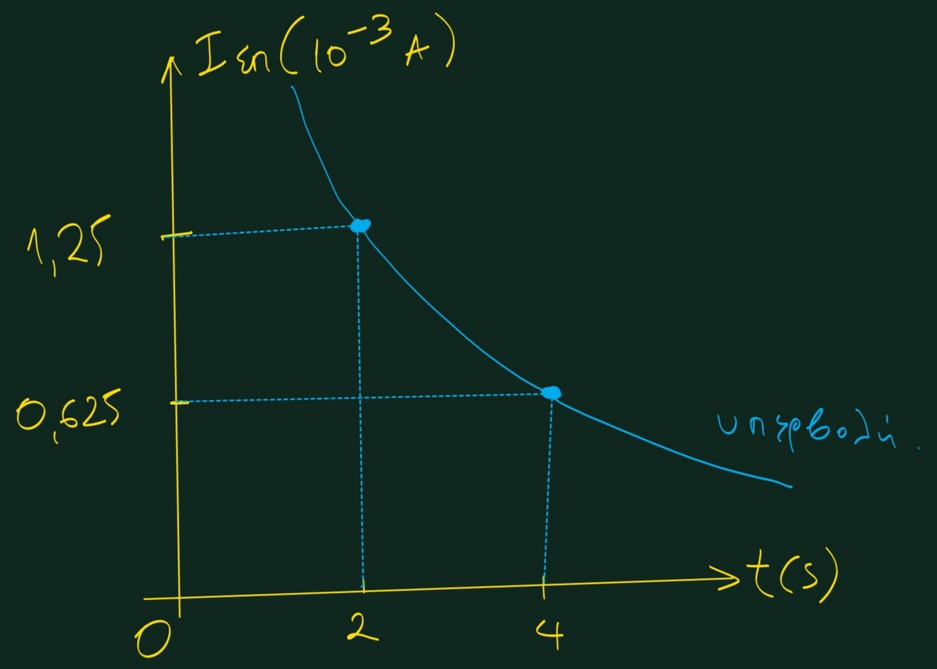
$= \dfrac{0{,}01\ \Omega}{0{,}01\ m} = 1\ \Omega/m$

Apa: $I_{\varepsilon n}(t) = \dfrac{2{,}5 \cdot 10^{-3}}{t}$ (SI) $t > 0$.

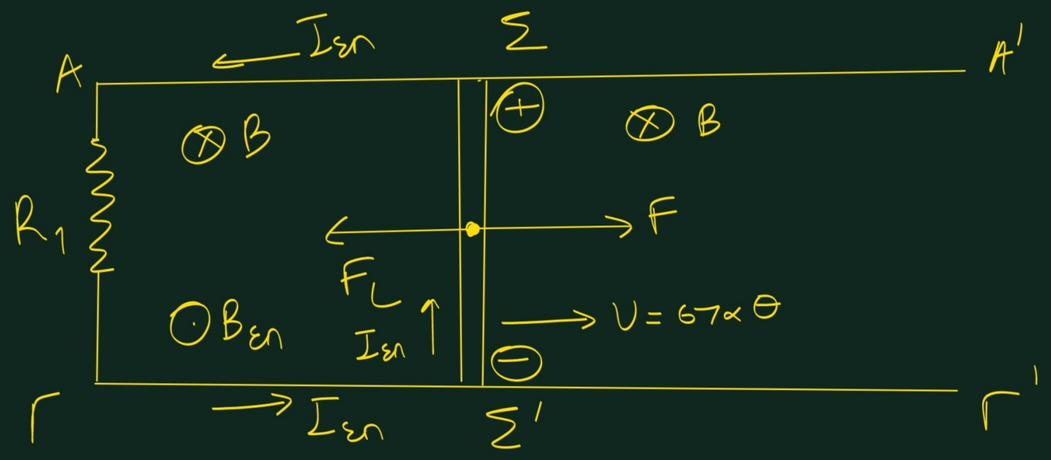
B) $I_{\varepsilon n}(2) = 1{,}25 \cdot 10^{-3}$ A

$I_{\varepsilon n}(4) = 0{,}625 \cdot 10^{-3}$ A.

γ)



Ασκ. 5.60 σελ. 223.



$m = 0{,}1\,kg$.

$L = 1\,m$.

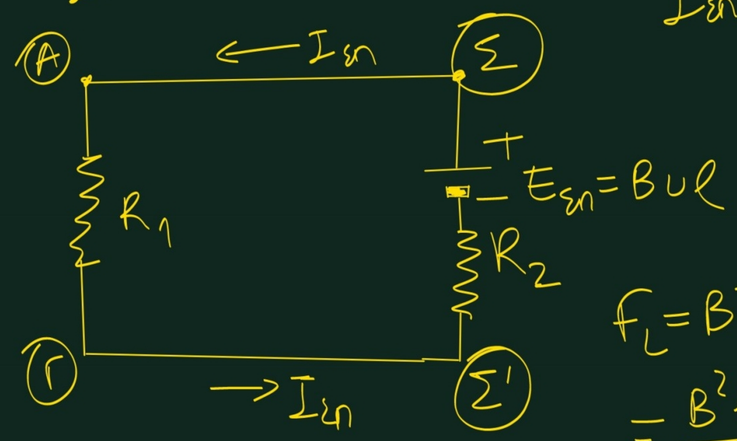
$R_2 = 0{,}5\,\Omega$ $\quad B = 0{,}2\,T$.

$R_1 = 0{,}1\,\Omega$

α) Γενικά έχουμε: $\Sigma F = ma \Rightarrow$

$F - F_L = ma$

Ισοδύναμο κύκλωμα.



$$I_{\varepsilon\pi} = \frac{Bvl}{R_1 + R_2}$$

$$F_L = BI_{\varepsilon\pi}l = \frac{B^2l^2v}{R_1 + R_2}$$

$$F - \frac{B^2l^2v}{R_1 + R_2} = ma.$$

Άρα η κίνηση του αγωγού είναι ευθύγραμμη <u>με</u> ομαλά επιταχυνόμενη με επιτάχυνση που διαρκώς μειώνεται μέχρι η ταχύτητα να γίνει μέγιστη, οριακή και σταθερή.

Αντιβάσταξη: $m \cdot \frac{du}{dt} = F - \frac{B^2 l^2 u}{R_1 + R_2} \Rightarrow$

$$\frac{m(R_1+R_2)}{B^2 l^2} \frac{du}{dt} = \frac{F(R_1+R_2)}{B^2 l^2} - u \Rightarrow$$

$$u_{op} - u = \tau \cdot \frac{du}{dt}$$

$$u_{op} = \frac{F(R_1+R_2)}{B^2 l^2} = \frac{1 \cdot 0,6}{0,2^2 \cdot 1^2} \Rightarrow u_{op} = \frac{0,6}{0,04} \Rightarrow$$

$l = L$ $\quad u_{op} = \frac{60}{4} \Rightarrow u_{op} = 15\, m/s.$

Η τάση στα άκρα του αγωγού είναι η πολική τάση.

$$V_{\Sigma'} - I_{\varepsilon\eta} \cdot R_2 + E_{\varepsilon\eta} = V_{\Sigma} \Rightarrow$$

$$V_{\Sigma} - V_{\Sigma'} = E_{\varepsilon\eta} - I_{\varepsilon\eta} \cdot R_2 \Rightarrow$$

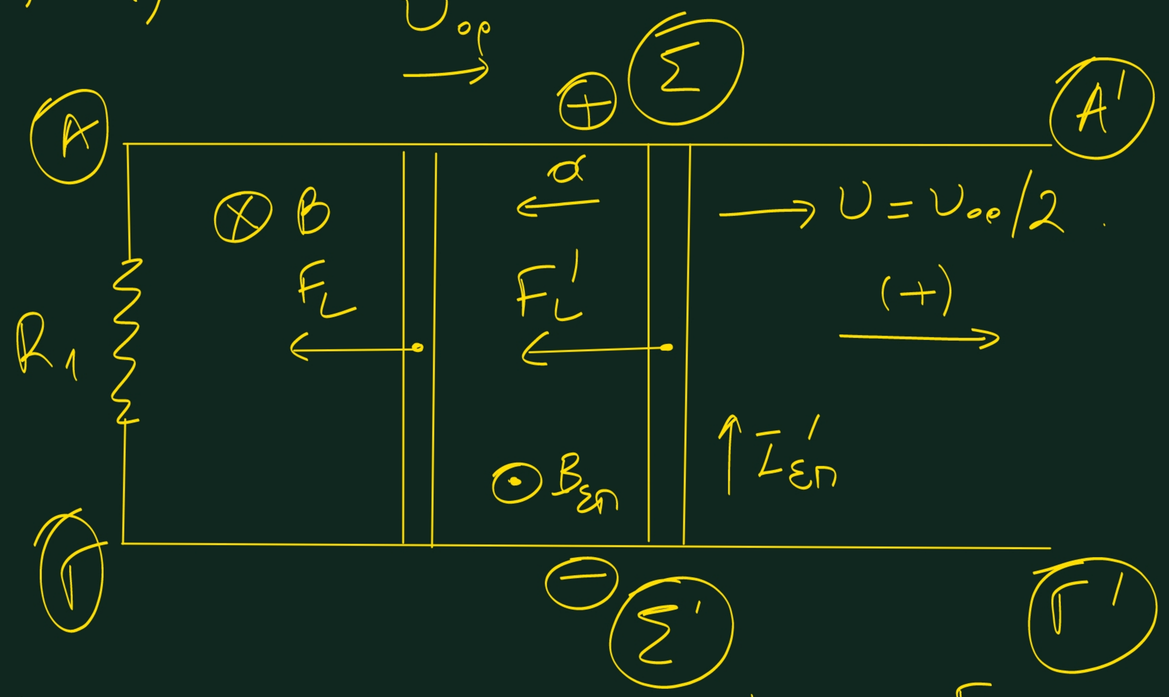
$$V_{\Sigma\Sigma'} = B u_{op} \cdot l - I_{\varepsilon\eta} \cdot R_2$$

$$I_{\varepsilon\eta} = \frac{B u_{op} \cdot l}{R_1 + R_2} = \frac{0,2 \cdot 15 \cdot 1}{0,6} = 5A$$

$$V_{\Sigma\Sigma'} = 0,2 \cdot 15 \cdot 1 - 5 \cdot 0,5 = 3 - 2,5 \Rightarrow$$

$$V_{\Sigma\Sigma'} = 0,5\, Volt$$

β) β1)



Από τη στιγμή που καταργείται η F ο αγωγός εκτελεί ευθύγραμμη μη ομαλά επιβραδυνόμενη κίνηση με επιβράδυνση και ταχύτητα που διαρκώς μειώνονται.

$$\Sigma F = -F_L' = -B I_{\varepsilon\pi}' \ell \Rightarrow$$

$$ma = -B \frac{B v \ell}{R_1 + R_2} \ell \Rightarrow$$

$$ma + \frac{B^2 \ell^2}{R_1 + R_2} v = 0 \Rightarrow$$

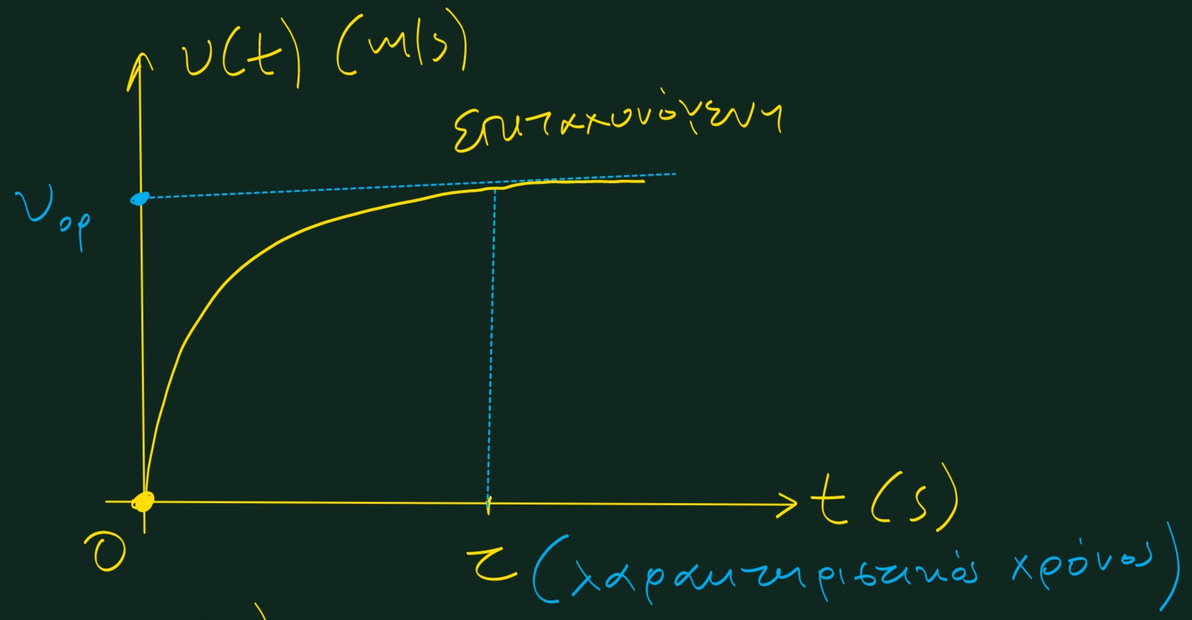
$$\frac{m \cdot (R_1 + R_2)}{B^2 \ell^2} \frac{\Delta v}{\Delta t} + v = 0 \Rightarrow$$

$$\tau \cdot \frac{\Delta v}{\Delta t} + v = 0 \Rightarrow v(t) = v(0) e^{-t/\tau}$$

Κατά την επιτάχυνση:

$$v + \tau \cdot \frac{dv}{dt} = v_{op}$$

και $v(t) = v_{op}(1 - e^{-t/\tau})$

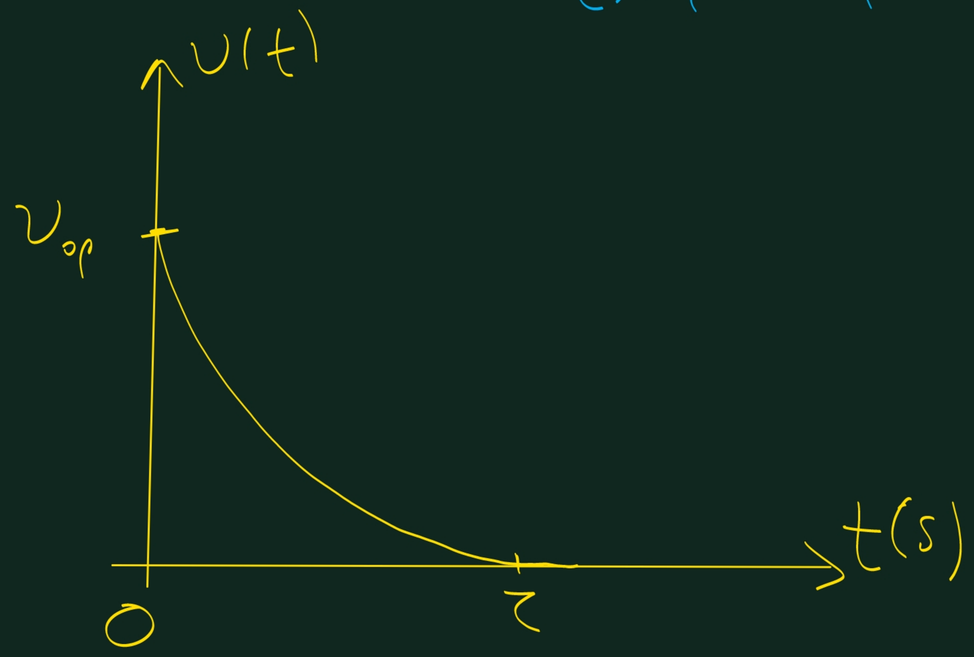


Κατά την επιβράδυνση:

$$v + \tau \frac{dv}{dt} = 0 \Rightarrow$$

$$v(t) = v(0) \cdot e^{-t/\tau} \Rightarrow$$

$$v(t) = v_{op} \cdot e^{-t/\tau}$$



$$ma = -\frac{B^2 l^2}{R_1+R_2} v \Rightarrow$$

$$\frac{dv}{dt} = -\frac{B^2 l^2}{m(R_1+R_2)} v$$

Αφ' ου $v = \frac{v_{op}}{2} = \frac{15}{2}$ m/s έχουμε:

$$\frac{dv}{dt} = -\frac{0{,}2^2 \cdot 1^2}{0{,}1 \cdot 0{,}6} \cdot \frac{15}{2} = -\frac{0{,}04}{0{,}06} \cdot \frac{15}{2} \Rightarrow$$

$$\frac{dv}{dt} = -\frac{2}{3} \cdot \frac{15}{2} \Rightarrow \frac{dv}{dt} = -5\,m/s^2$$

$$\frac{\Delta K}{\Delta t} = \pm \frac{\Sigma F \cdot \Delta x}{\Delta t} = \pm \Sigma F \cdot v$$

$$K(t) = \frac{1}{2} m (v(t))^2 \Rightarrow$$

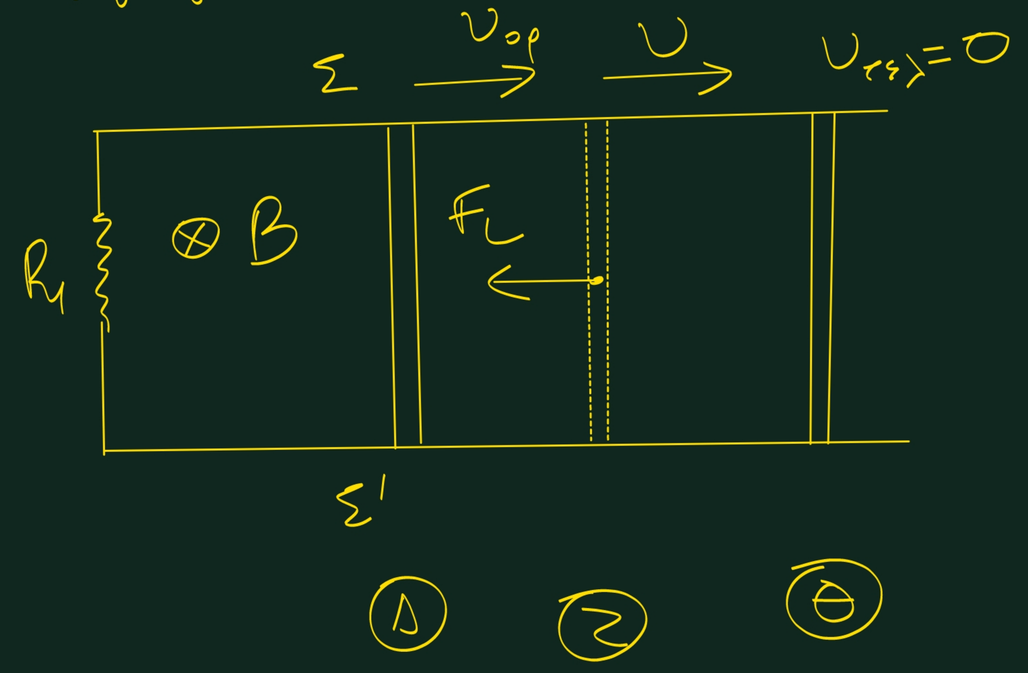
$$\frac{dK}{dt} = \frac{1}{2} m \cdot \frac{d\,v^2(t)}{dt} =$$

$$= \frac{1}{2} \cdot m \cdot 2 \cdot v(t) \cdot \frac{dv}{dt}$$

$$= mv \cdot \frac{dv}{dt} = 0{,}1 \cdot \frac{15}{2} \cdot (-5) =$$

$$= -\frac{7{,}5}{2} \Rightarrow \frac{dK}{dt} = -3{,}75\ J/sec$$

B2) Κατά την επιβράδυνση, η μοναδική δύναμη που ασκείται στον αγωγό, είναι η δύναμη Laplace.



Από την ΑΔΕ:

$$K_\Delta + \cancel{U_\Delta}^{\,0} + W_{F_L} = K_\Theta + \cancel{U_\Theta}^{\,0} \Rightarrow$$

$$\frac{1}{2} m \upsilon_{op}^2 + W_{F_L} = 0 \Rightarrow$$

$$W_{F_L} = -\frac{1}{2} m \cdot \upsilon_{op}^2 = -\frac{1}{2} \cdot 0{,}1 \cdot 225 = -\frac{22{,}5}{2} \Rightarrow$$

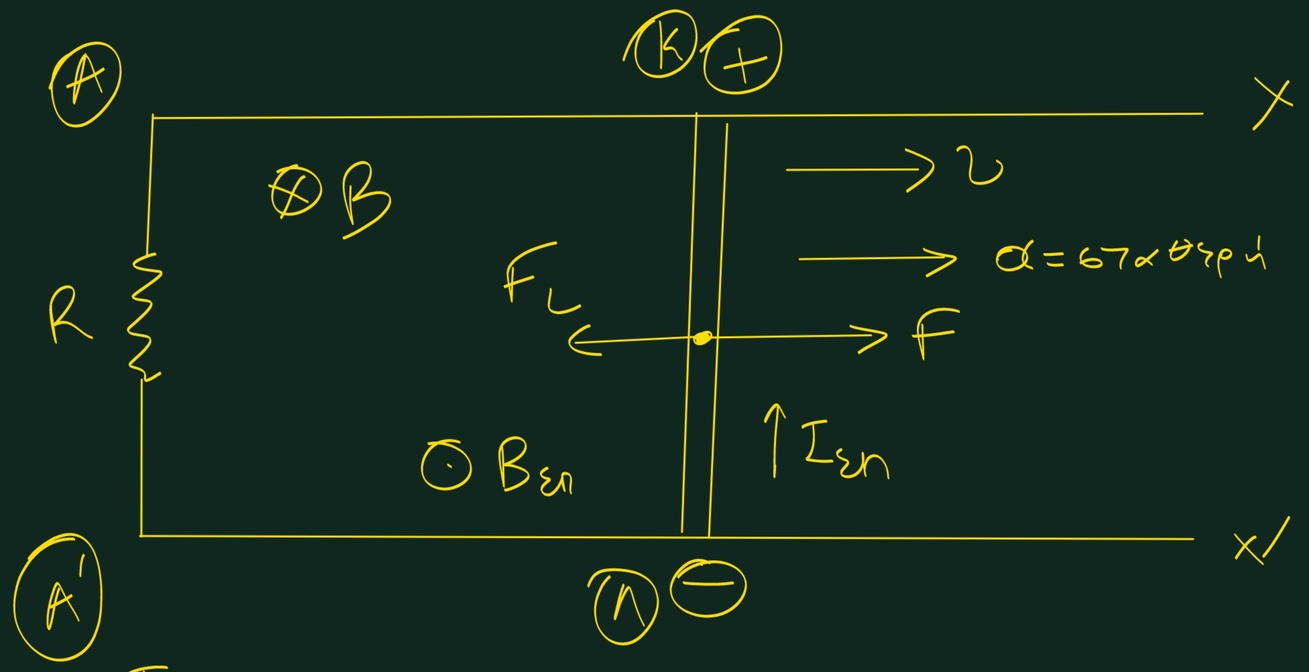
$$W_{F_L} = -11{,}25 \text{ Joule}.$$

Άρα: $Q_{R_{ολ}} = |W_{F_L}| = 11{,}25$ Joule.

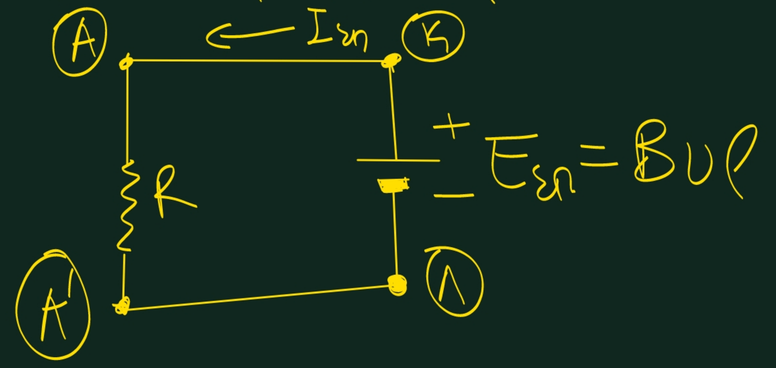
$$Q_{R_{ολ}} = \sum I_{επ}^2 (R_1+R_2) \cdot \Delta t = \sum \frac{B^2 \upsilon^2 \ell^2}{R_1+R_2} \cdot \Delta t = \sum \frac{B^2 \upsilon \ell^2}{R_1+R_2} \cdot \upsilon \cdot \Delta t = \sum F_L \cdot \Delta x =$$

$$= |W_{F_L}|$$

Ασκ. 5.62 (σελ. 224)



Ισοδύναμο κύκλωμα:



$\upsilon = at$ $\qquad E_{\varepsilon\eta} = B\upsilon l = Blat$

$$I_{\varepsilon\eta} = \frac{Blat}{R}$$

$$F - F_L = ma \Rightarrow F - BI_{\varepsilon\eta} l = ma \Rightarrow$$

$$F - B \cdot \frac{Blat}{R} \cdot l = ma \Rightarrow$$

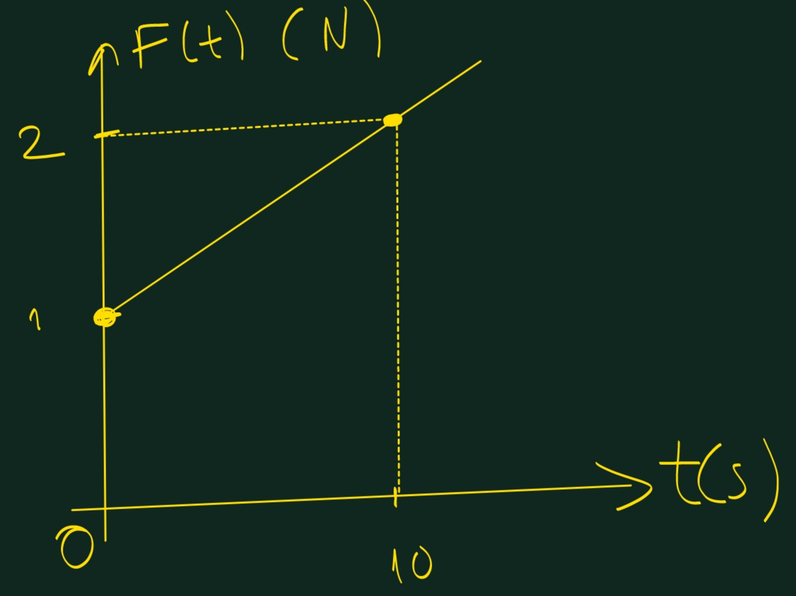
$$F(t) = ma + \frac{B^2 l^2 a}{R} \cdot t \Rightarrow$$

$$F(t) = 0{,}5 \cdot 2 + \frac{0{,}5^2 \cdot 1 \cdot 2}{5} t \Rightarrow$$

$$F(t) = 1 + 0{,}05 \cdot 2 \cdot t \Rightarrow F(t) = 1 + 0{,}1t$$

$$(t \geq 0)$$

$F(t) = 1 + 0{,}1t \quad (t \geq 0)$

$F(0) = 1\,N$

$F(10) = 2\,N$