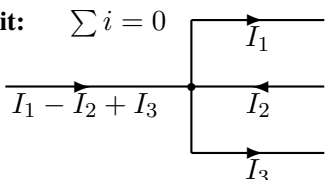
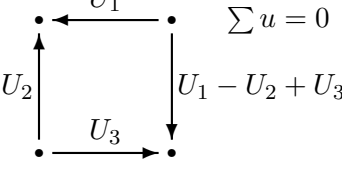
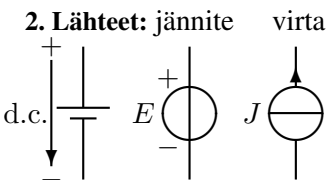
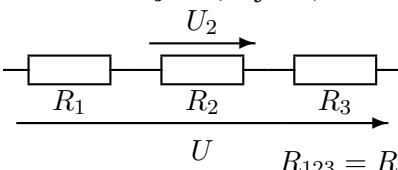


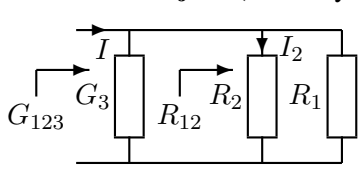
# ELEC-C4210 SÄHKÖTEKNIikka JA ELEKTRONIIKKA Kaavakokoelma *Kako* 19.9.2022 © X

Ota *Kako* mukaan välikokeisiin ja tenttiin. Kaikki kaavat eivät ole yleispäteviä. Selvitä itsellesi kirjainten merkitys, ja milloin mitään laskutapaa voi käyttää. Älä opettele muita kaavoja ulkoa. Prefiksit: y, z, a, f, p, n,  $\mu$ , m, l, k, M, G, T, P, E, Z, Y. Kreikkalaiset: alfa  $\alpha$ , beta  $\beta$ , gamma  $\gamma$   $\Gamma$ , delta  $\delta$   $\Delta$ , epsilon  $\epsilon$ , zeta  $\zeta$ , eta  $\eta$ , theta  $\theta$ , jota  $\iota$ , kappa  $\kappa$ , lamda  $\lambda$   $\Lambda$ , myy  $\mu$ , nyy  $\nu$ , ksi  $\xi$ , omikron o, pii  $\pi$   $\Pi$ , rho  $\rho$ , sigma  $\sigma$   $\Sigma$ , tau  $\tau$ , ypsilon  $\upsilon$ , phi  $\varphi$ , khi  $\chi$ , psi  $\psi$ , omega  $\omega$   $\Omega$ .

**1. Kirchhoffin lait:**  $\sum i = 0$    $\sum u = 0$  

**2. Lähteet:** jännite  virta

**3. Jännitteen jako (sarjassa):**  $U_2 = \frac{R_2}{R_1+R_2+R_3}U$    $R_{123} = R_1 + R_2 + R_3$

**4. Virran jako (rinnankytkennässä):**  $I_2 = \frac{G_2}{G_1+G_2+G_3}I$    $R_{12} = \frac{R_1 R_2}{R_1 + R_2} = \frac{1}{\frac{1}{G_{12}}}$   
 $G_{123} = G_3 + \overbrace{G_2 + G_1}^{G_{12}}$

**5. Virtauskenttä:**  $U = El$   $I = JA$   $E = \rho J = \frac{J}{\sigma}$

**6. Resistanssi ja konduktanssi:**  $R = \frac{l}{G} = \frac{\rho l}{A}$

**7. Vastus:**  $R = \frac{\rho l}{A}$   $G = \frac{1}{R} = \frac{\sigma A}{l}$

**8. Tasokondensaattori:**  $C = \frac{\epsilon A}{l}$

**9. Lieriökäämi:**  $L = N^2 \frac{\mu A}{l}$

**10. Sähkökenttä:**  $E = \frac{U}{l}$   $D = \epsilon E$   $\psi = Q = DA$   $\epsilon = \epsilon_r \epsilon_0$   $\epsilon_0 = 8,854 \cdot 10^{-12} \frac{F}{m} = \frac{1}{c_0^2 \mu_0} \approx \frac{1}{36\pi} \frac{nF}{m}$

**11. Magneettikenttä:**  $H = \frac{U_m}{l}$   $U_m = NI$   $B = \mu H$   $\psi = N\phi$   $\phi = BA$   $\mu = \mu_r \mu_0$   $\mu_0 = 4\pi \cdot 10^{-7} \frac{H}{m}$

**12. Kapasitanssi:**  $i = C \frac{du}{dt} \Leftrightarrow u = \frac{1}{C} \int_0^t i dt + U_{C0}$   $i = \frac{dq}{dt}$   $C = \frac{Q}{U}$   $w_C = \frac{1}{2} C u^2$   $u = u(t)$

**13. Induktanssi:**  $u = L \frac{di}{dt} \Leftrightarrow i = \frac{1}{L} \int_0^t u dt + I_{L0}$   $u = \frac{d\psi}{dt}$   $L = \frac{\psi}{I}$   $w_L = \frac{1}{2} L i^2$   $i = i(t)$

**14. Muutosilmiöt:**  $U_{C0} = u_C(0^-) = u_C(0^+)$   $I_{L0} = i_L(0^-) = i_L(0^+)$  **Yritteet:**  $\left. \begin{matrix} i(t) \\ u(t) \end{matrix} \right\} = \left\{ \begin{matrix} i(\infty) + [i(0) - i(\infty)] e^{-\frac{t}{\tau}} \\ B + A e^{-\frac{t}{\tau}} \end{matrix} \right.$   $\tau = \begin{cases} RC \\ L/R \end{cases}$

**15. Tehollisarvo:**  $U = \sqrt{\frac{1}{T} \int_0^T u^2 dt} = \sqrt{\sum U_i^2}$

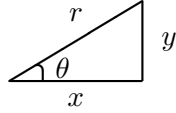
**16. Keskiarvot:**  $U_{av} = \frac{1}{T} \int_0^T u dt$   $U_r = \frac{1}{T} \int_0^T |u| dt$

**17. Sinimuotoinen virta tai jännite:**  $u(t) = \hat{u} \sin(\omega t + \phi) = \text{Im}[\hat{u} e^{j(\omega t + \phi)}]$   $\hat{u} = \sqrt{2} |U| = \frac{\pi}{2} U_r$   $\hat{i} = \sqrt{2} |I|$

**18. Osoitinlaskenta ( $i, u$ ):**  $i(t) = \hat{i} \sin(\omega t + \phi) \Leftrightarrow \underline{I} = \frac{\hat{i}}{\sqrt{2}} \angle \phi$

**19. Kulmataajuus:**  $\omega = 2\pi f = 2\pi/T$

**20. Kompleksiluvut:**  $\left\{ \begin{matrix} z_1 = 4 + j2 = \sqrt{20} \angle 26,6^\circ = \sqrt{20} e^{j \frac{\pi}{6,776}} & (26,565^\circ = \alpha) \\ z_2 = 3 + j1 = \sqrt{10} \angle 18,4^\circ = \sqrt{10} e^{j \frac{\pi}{9,764}} & (18,435^\circ = \beta) \end{matrix} \right.$   $j = \pm \sqrt{-1}$

**21. Koordinaatistomuunnos:**  $\begin{cases} x = |r| \cos \theta \\ y = |r| \sin \theta \end{cases}$   $\begin{cases} r = \sqrt{x^2 + y^2} = |z| \\ \theta = \arctan(y/x) \end{cases}$  

**22. Summamuoto:**  $\left\{ \begin{matrix} z_1 + z_2 = (4 + 3) + j(2 + 1) = 7 + j3 & z_1 z_2 = (4 \cdot 3 - 2 \cdot 1) + j(4 \cdot 1 + 2 \cdot 3) = 10 + j10 \\ z_1 - z_2 = (4 - 3) + j(2 - 1) = 1 + j & \frac{z_1 z_2^*}{z_2 z_1^*} = \frac{(4 \cdot 3 + 2 \cdot 1) + j(2 \cdot 3 - 4 \cdot 1)}{3^2 + 1^2} = 1,4 + j0,2 \end{matrix} \right.$

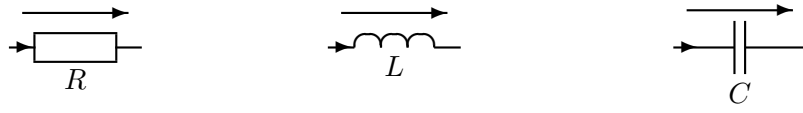
**23. Kulmamuuoto, kerto:**  $z_1 z_2 = \sqrt{20} \sqrt{10} \angle (\alpha + \beta) = \sqrt{200} \angle 45^\circ$  **Jako:**  $\frac{z_1}{z_2} = \frac{\sqrt{20}}{\sqrt{10}} \angle (\alpha - \beta) = \sqrt{2} \angle 8,13^\circ$

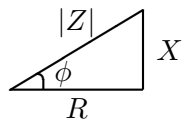
**24. Liittoluku ja itseisarvo:**  $z = x + jy = |z| \angle \theta \Leftrightarrow z^* = x - jy = |z| \angle -\theta$   $z z^* = |z|^2$   $|z| = \sqrt{x^2 + y^2}$

**25. Impedanssi:**  $U = ZI$   $Z = R + jX$

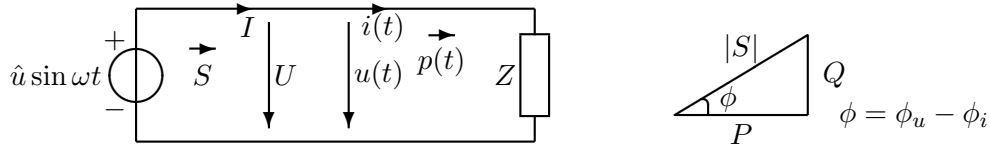
**26. Admittanssi:**  $I = YU$   $Y = G + jB = \frac{1}{Z} = \frac{R - jX}{R^2 + X^2}$

**27. Vastus:**  $Z_R = R$  **28. Kela:**  $Z_L = j\omega L$  **29. Kondensaattori:**  $Z_C = \frac{1}{j\omega C} = -j \frac{1}{\omega C}$

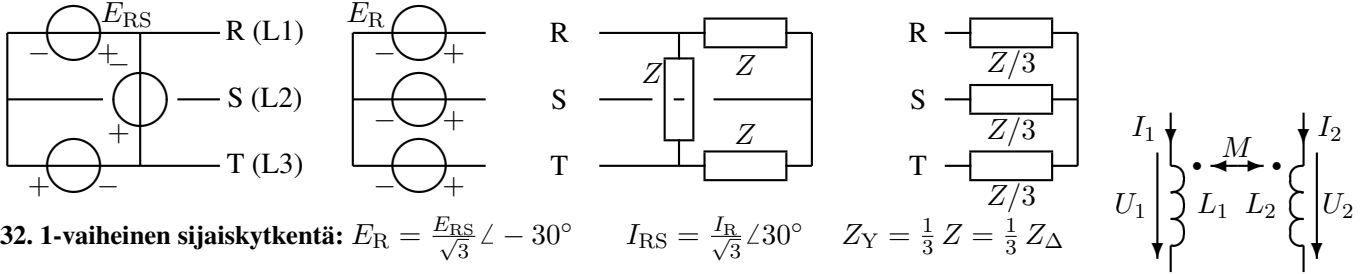




30. Teho:  $S = UI^* = P + jQ \Rightarrow P = \frac{1}{T} \int_0^T p(t) dt = |U||I| \cos \phi \quad Q = |U||I| \sin \phi \quad p(t) = u(t)i(t)$



31. Kolmivaihejärjestelmä ( $U, I$ ):  $U_R = U \angle 0^\circ \quad U_S = U \angle -120^\circ \quad U_T = U \angle -240^\circ = U \angle +120^\circ$



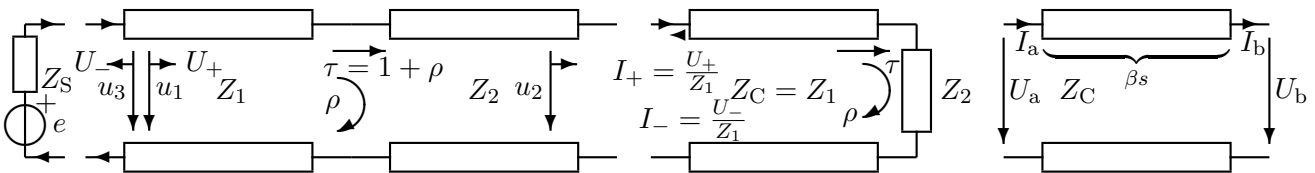
32. 1-vaiheinen sijaiskytkentä:  $E_R = \frac{E_{RS}}{\sqrt{3}} \angle -30^\circ \quad I_{RS} = \frac{I_R}{\sqrt{3}} \angle 30^\circ \quad Z_Y = \frac{1}{3} Z = \frac{1}{3} Z_\Delta$

33. Muuntajayhtälöt ja kytkentäkerroin:  $\begin{cases} U_1 = j\omega L_1 I_1 + j\omega M I_2 \\ U_2 = j\omega M I_1 + j\omega L_2 I_2 \end{cases} \quad k = \frac{M}{\sqrt{L_1 L_2}} (\approx \pm 1 \quad \frac{U_2}{U_1} \approx \frac{M}{L_1} \quad \frac{I_1}{-I_2} \approx \frac{L_2}{M})$

34. Epätahtimoottorin jättämä, tahtinopeus ja napajako:  $s = \frac{n_s - n}{n_s} \quad n_s = \frac{f}{p} \quad \tau = \frac{180^\circ}{p}$

35. Ominaisimpedanssi ja aallon nopeus:  $Z_C = \frac{U_+}{I_+} = \frac{U_-}{I_-} = \sqrt{\frac{l}{c}} \quad v = \frac{s}{\Delta t} = \frac{c_0}{\sqrt{\epsilon_r \mu_r}} = \frac{1}{\sqrt{l c}} \quad c_0 \approx 2,998 \cdot 10^8 \text{ m/s}$

36. Heijastus- ja läpäisykerroin:  $\rho = \frac{u_3}{u_1} = \frac{Z_2 - Z_1}{Z_2 + Z_1} \quad \tau = \frac{u_2}{u_1} = 1 + \rho = \frac{2Z_2}{Z_2 + Z_1} \quad u_1(0) = U_+ = Z_1 \frac{e}{Z_S + Z_1}$



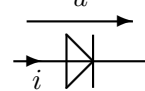
37. Siirtojohtoyhtälöt (sini):  $\begin{cases} U_a = U_b \cos \beta s + jZ_C I_b \sin \beta s \\ I_a = j \frac{U_b}{Z_C} \sin \beta s + I_b \cos \beta s \end{cases} \quad \beta = \frac{\omega}{v} = \frac{2\pi}{\lambda} = \frac{360^\circ}{\lambda} \quad v = \lambda f$

38. Diodi:  $\begin{cases} i = I_S (e^{\frac{u}{nU_T}} - 1) \\ u = nU_T \ln \frac{i + I_S}{I_S} \end{cases} \quad i \approx \begin{cases} I_S (e^{\frac{u}{nU_T}}) & (U \gg nU_T) \\ I_S (-1) & (U \ll 0) \end{cases} \quad U_T = \frac{kT}{q} \approx 25 \text{ mV} \quad n \approx 2 \quad \frac{1}{nU_T} = 20 \frac{1}{V}$

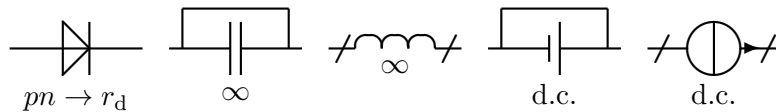
$q = 1,602 \cdot 10^{-19} \text{ As}$

$k = 1,381 \cdot 10^{-23} \frac{\text{J}}{\text{K}}$

$r_d = \frac{1}{\frac{\partial i}{\partial u} \Big|_U} = \frac{nU_T}{I}$

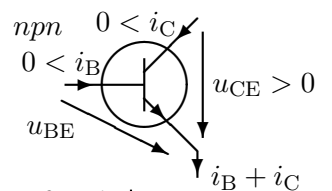


39. Piensignaalianalyysi:

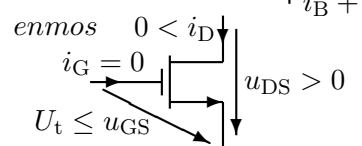


40. Transistori (BJT):  $i_C = \beta i_B = \alpha i_E$  kun  $u_{CE} \geq 0,3 \text{ V} \quad u_{BE} \approx 0,7 \text{ V} \quad i_C \approx I_S e^{\frac{u_{BE}}{U_T}}$

$r_\pi = \frac{nU_T}{I_B} = \frac{u_{be}}{i_b} \quad g_m = \frac{\beta}{r_\pi} \quad i_c = \beta i_b = g_m u_{be} \quad r_o = \frac{U_A}{I_C} \quad n \approx 1$

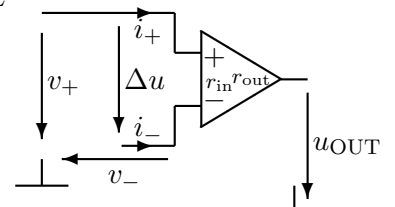


41. FET:  $\begin{cases} \text{CUT: } u_{GS} \leq U_t \Rightarrow i_D = 0 \\ \text{OHM: } u_{DS}^2 \approx 0: & i_D = i_S \approx \overbrace{2K(u_{GS} - U_t)}^{\approx 1/r_{DS}} u_{DS} \\ \text{TRI: } u_{DS} \leq u_{GS} - U_t: & i_D = i_S = K[2(u_{GS} - U_t)u_{DS} - u_{DS}^2] \\ \text{SAT: } u_{DS} \geq u_{GS} - U_t: & i_D = i_S = K(u_{GS} - U_t)^2 \end{cases}$



$i_d = g_m u_{gs} \quad g_m = 2K(u_{GS} - U_t) = 2\sqrt{KI_D} \quad r_o = \frac{U_A}{I_D} \quad K = \frac{1}{2} \mu_{n(p)} C_{OX} \frac{W}{L}$

42. Operaatiovahvistin:  $\begin{cases} v_+ = v_- \Rightarrow \Delta u = 0 \\ i_+ = 0 \\ i_- = 0 \end{cases} \quad \begin{cases} A_u = \frac{u_{OUT}}{\Delta u} = \infty \\ r_{in} = \infty \\ r_{out} = 0 \end{cases}$



43. Tehoelektronikka:  $\Delta Q = C \Delta u = I \Delta t \quad \Delta \psi = L \Delta i = U \Delta t \quad \Delta T = T_A - T_B = \theta_{AB} P = R_{TH} P$