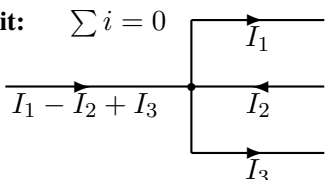
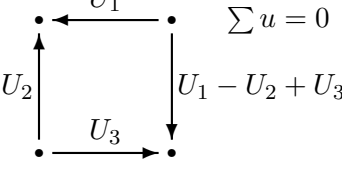
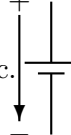
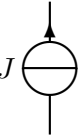
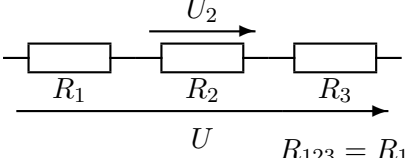
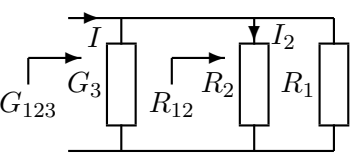


Ota *Kako* mukaan välikokeisiin ja tenttiin. Kaikki kaavat eivät ole yleispäteviä. Selvitä itsellesi kirjainten merkitys, ja milloin mitäänkin laskutapaa voi käyttää. Älä opettele muita kaavoja ulkoa. Prefiksit: y, z, a, f, p, n, μ , m, l, k, M, G, T, P, E, Z, Y. Kreikkalaiset: alfa α , beta β , gamma γ Γ , delta δ Δ , epsilon ϵ , zeta ζ , eta η , theta θ , jota ι , kappa κ , lamda λ Λ , myy μ , nyy ν , ksi ξ , omikron o, pii π Π , rho ρ , sigma σ Σ , tau τ , ypsilon υ , phi φ , khi χ , psi ψ , omega ω Ω .

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

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

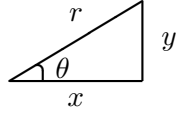
16. Keskiarvot: $U_{av} = \frac{1}{T} \int_0^T u dt$ $U_r = \frac{1}{T} \int_0^T |u| dt$

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

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

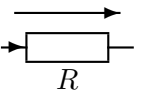
22. Summamuoto: $\begin{cases} z_1 + z_2 = (4 + 3) + j(2 + 1) = 7 + j3 & z_1 z_2 = (4 \cdot 3 - 2 \cdot 1) + j(4 \cdot 1 + 2 \cdot 3) = 10 + j10 \\ z_1 - z_2 = (4 - 3) + j(2 - 1) = 1 + j & \frac{z_1 z_2^*}{z_2 z_2^*} = \frac{(4 \cdot 3 + 2 \cdot 1) + j(2 \cdot 3 - 4 \cdot 1)}{3^2 + 1^2} = 1,4 + j0,2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

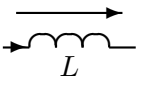
23. Kulmamuoto, kerto: $z_1 z_2 = \sqrt{20} \sqrt{10} \angle (\alpha + \beta) = \sqrt{200} \angle 45^\circ$ **Jako:** $\frac{z_1}{z_2} = \frac{\sqrt{20}}{\sqrt{10}} \angle (\alpha - \beta) = \sqrt{2} \angle 8,13^\circ$

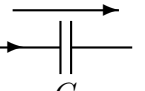
24. Liittoluku ja itseisarvo: $z = x + jy = |z| \angle \theta \Leftrightarrow z^* = x - jy = |z| \angle -\theta$ $z z^* = |z|^2$ $|z| = \sqrt{x^2 + y^2}$

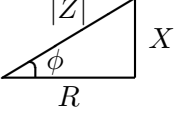
25. Impedanssi: $U = ZI$ $Z = R + jX$

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

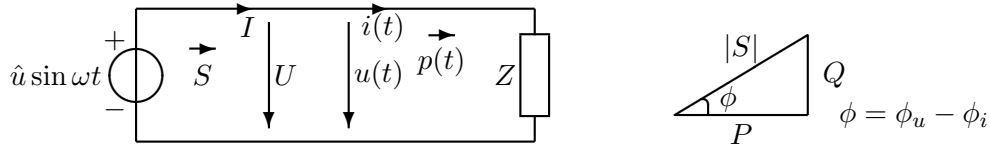
27. Vastus: $Z_R = R$ 

28. Kela: $Z_L = j\omega L$ 

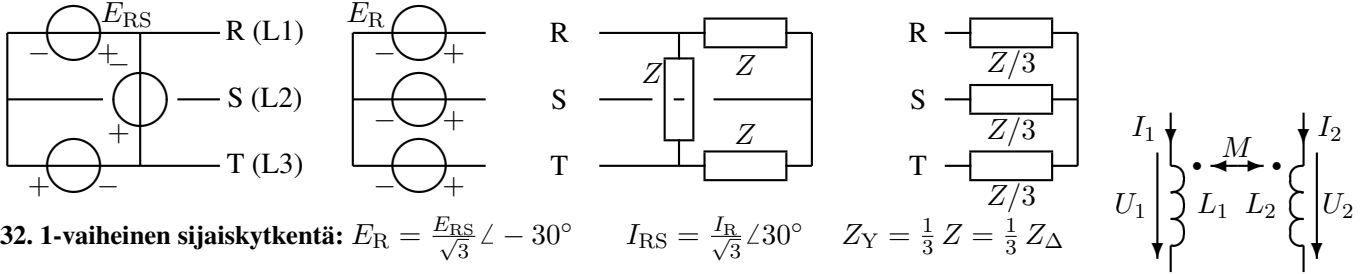
29. Kondensaattori: $Z_C = \frac{1}{j\omega C} = -j \frac{1}{\omega C}$ 



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): $U_R = U \angle 0^\circ \quad U_S = U \angle -120^\circ \quad U_T = U \angle -240^\circ = U \angle +120^\circ$



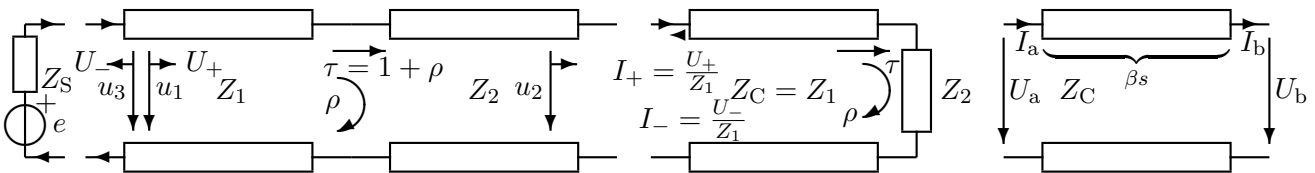
32. 1-vaiheinen sijaiskytkentä: $E_R = \frac{E_{RS}}{\sqrt{3}} \angle -30^\circ \quad I_{RS} = \frac{I_R}{\sqrt{3}} \angle 30^\circ \quad Z_Y = \frac{1}{3} Z = \frac{1}{3} Z_\Delta$

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

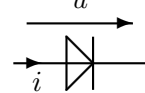
36. Heijastus- ja läpäisykerroin: $\rho = \frac{u_3}{u_1} = \frac{Z_2 - Z_1}{Z_2 + Z_1} \quad \tau = \frac{u_2}{u_1} = 1 + \rho = \frac{2Z_2}{Z_2 + Z_1} \quad u_1(0) = U_+ = Z_1 \frac{e}{Z_S + Z_1}$



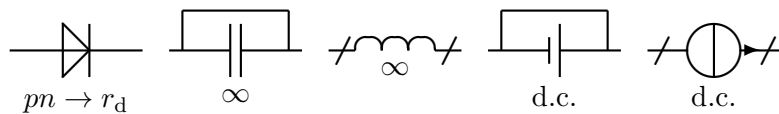
37. Siirtojohtoyhtälöt (sini): $\begin{cases} U_a = U_b \cos \beta s + jZ_C I_b \sin \beta s \\ I_a = j \frac{U_b}{Z_C} \sin \beta s + I_b \cos \beta s \end{cases} \quad \beta = \frac{\omega}{v} = \frac{2\pi}{\lambda} = \frac{360^\circ}{\lambda} \quad v = \lambda f$

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

$q = 1,602 \cdot 10^{-19} \text{ As} \quad k = 1,381 \cdot 10^{-23} \frac{\text{J}}{\text{K}} \quad r_d = \frac{1}{\frac{\partial i}{\partial u} \Big|_U} = \frac{nU_T}{I}$

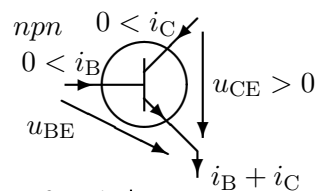


39. Piensignaalianalyysi:

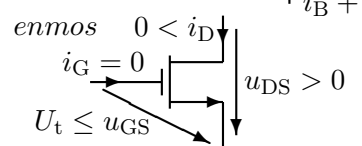


40. Transistori (BJT): $i_C = \beta i_B = \alpha i_E$ kun $u_{CE} \geq 0,3 \text{ V} \quad u_{BE} \approx 0,7 \text{ V} \quad i_C \approx I_S e^{\frac{u_{BE}}{U_T}}$

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

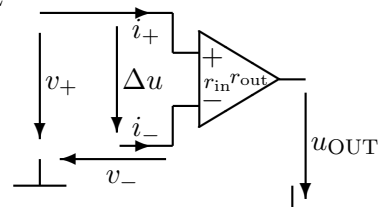


41. FET: $\begin{cases} \text{CUT: } u_{GS} \leq U_t \Rightarrow i_D = 0 \\ \text{OHM: } u_{DS}^2 \approx 0: & i_D = i_S \approx \overbrace{2K(u_{GS} - U_t)}^{\approx 1/r_{DS}} u_{DS} \\ \text{TRI: } u_{DS} \leq u_{GS} - U_t: & i_D = i_S = K[2(u_{GS} - U_t)u_{DS} - u_{DS}^2] \\ \text{SAT: } u_{DS} \geq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



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

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