

ELECTROTECHNICS EXERCISE BOOK

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v 1.0

This exercise book has been prepared to support the teaching of Electrical Engineering course offered at Széchenyi István University, primarily for students of Mechatronics and Mechanical Engineering.

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Although every effort has been made to ensure accuracy, occasional errors or typographical mistakes may still occur. Feedback and corrections are warmly welcomed at:

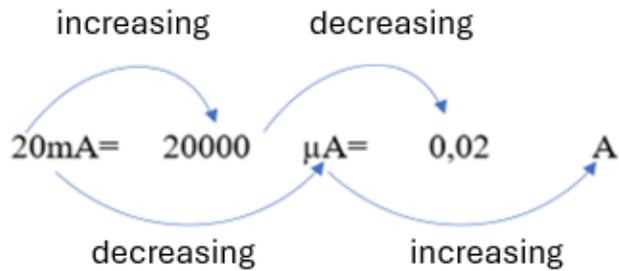
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1. PREFIXES AND UNIT CONVERSIONS

1.1 Carry out the following conversions considering the prefixes!

EXAMPLE**PROBLEMS**

$5000\text{mA} =$	A	
$20\text{mA} =$	$\mu\text{A} =$	A
$1,2\text{A} =$	mA	
$500\text{mA} =$	A	
$2000\mu\text{A} =$	$\text{mA} =$	A
$50\mu\text{A} =$	mA	
$10\text{A} =$	$\text{mA} =$	μA
$5\text{kA} =$	A	
$1750\text{A} =$	$\text{kA} =$	MA
$10\text{mA} =$	$\mu\text{A} =$	A
$0,9\text{A} =$	mA	
$20\text{mV} =$	V	
$1500\mu\text{V} =$	$\text{mV} =$	V
$100\mu\text{V} =$	$\text{mV} =$	V
$1,5\text{kV} =$	V	
$1\text{V} =$	$\text{mV} =$	μV
$50\text{V} =$	kV	
$95000\text{V} =$	kV	
$230\text{V} =$	$\text{kV} =$	MV

$$0.06\text{kV} = \quad \text{V}$$

$$1000\text{k}\Omega = \quad \Omega$$

$$1\text{M}\Omega = \quad \text{k}\Omega = \quad \Omega$$

$$0.5\text{M}\Omega = \quad \text{k}\Omega = \quad \Omega$$

$$30\text{k}\Omega = \quad \text{M}\Omega = \quad \Omega$$

$$1\text{m}\Omega = \quad \Omega$$

$$3\Omega = \quad \text{m}\Omega = \quad \text{k}\Omega$$

2. ELECTRIC CHARGE AND CURRENT

EXAMPLE

During 90min of operation, the power supply of a radio delivered a total charge of 300C to the device's circuits. What was the current consumption of the circuits in milliamperes?

$$t = 90 \text{ min} = 5400\text{s}$$

$$Q = 300\text{C} = 300\text{As}$$

$$I = ?$$

$$I = \frac{Q}{t} = \frac{300\text{As}}{5400\text{s}} = 0.0556\text{A} = 55.56\text{mA}$$

PROBLEMS

2.1 A light bulb draws a current of 200mA. How much charge passes through it if it remains switched on for half an hour? (360C)

2.2 A power source delivers a current of 1,5A for 0.5 hours. How much electric charge leaves the terminals of the source? (2700C)

2.3 What amount of charge flows through a conductor in 1min if the current is 2A? (120C)

2.4 The current in a wire is 5A. How long does it take for a total charge of 100C to pass through the wire? (20s)

2.5 During 90min of operation, the power supply of a radio delivered a total charge of 300C to the device's circuits. What was the current consumption of the circuits in milliamperes? (55.56mA)

2.6 Calculate the current flowing through the cord of an iron if a total charge of 7800C passes through it in 30min. (4.33A)

2.7 An accumulator (battery) was discharged with a current of 300mA for 10h. How much charge did the accumulator deliver during this time? (10800C)?

2.8 During the 1/500-s operation of a camera flash, a current of 300mA flows through the circuit. Calculate the amount of charge used by the flash. (0.6mC)

2.9 Complete the table!

Q	t	I [A]	I [mA]
35C	700s		
5.4C	30min		
144C	2h		
	200s		50
225C		9	
36C			66.67

2.10 In which case is the electric current greater? When a charge of 0,6C passes through a conductor in 15s, or when a charge of 18C passes through it in 1.5min? (Answers: $I_1=0.04A$; $I_2=0.2A$)

2.11 My brother-in-law left the car lights on. The lamp draws a current of 3A. After how much time will the battery be completely discharged if its capacity is 40Ah? (13.3h)

2.12 A 12V rated battery has a capacity of 55Ah.

- Calculate how much charge it stores when fully charged. (198000C)
- What was the discharge current if its charge dropped from 55Ah to 25Ah over 12h? (2.5A)
- How long will it take to recharge the battery from 25Ah to 55Ah if the charger provides a constant current of 4A? (Answer: 7.5h)

3. RESISTIVITY

EXAMPLE

Determine the resistance of a solid iron conductor with a length of 200m and a diameter of

27.5mm, if its resistivity is $\rho = 0.1 \frac{\Omega mm^2}{m}$.

$$\rho = 0.1 \frac{\Omega mm^2}{m}$$

$$l = 200m$$

$$d = 27.5mm$$

$$R = ?$$

$$A = \frac{d^2 \pi}{4} = \frac{27.5^2 mm \cdot \pi}{4} = 593.96 mm^2$$

$$R = \rho \frac{l}{A} = 0.1 \frac{\Omega \text{mm}^2}{\text{m}} \frac{200\text{m}}{593.96\text{mm}^2} = 33.67\text{m}\Omega$$

PROBLEMS:

3.1 What can be inferred from the specific resistivity values $\rho_{\text{iron}} = 0.1 \frac{\Omega \text{mm}^2}{\text{m}}$ and copper $0.017 \frac{\Omega \text{mm}^2}{\text{m}}$?

3.2 Determine the DC resistance of a wire with a specific resistivity of $\rho = 0.0175 \frac{\Omega \text{mm}^2}{\text{m}}$, a length of 20 m, and a cross-sectional area of $A = 0.25\text{mm}^2$. ($R = 1.4 \Omega$)

3.3 Determine the resistance of a solid iron pipe with a specific resistivity of $\rho = 0.1 \frac{\Omega \text{mm}^2}{\text{m}}$, a length of 200m, and a diameter of $d = 27.5\text{mm}$. ($33.67\text{m}\Omega$)

3.4 What is the resistance of a 3.5km long telephone circuit connecting subscribers, implemented with copper wire of 2 mm diameter (the line consists of two conductors, i.e. a wire pair)? ($\rho = 0.0175 \frac{\Omega \text{mm}^2}{\text{m}}$) (38.99Ω)?

a. How does the resistance change if the length of the wire remains constant but its cross-sectional area is reduced to half? (77.986Ω)

b. How does the resistance change if the length of the wire is reduced to half while the cross-sectional area remains unchanged? (19.496Ω)

3.5 What is the resistance of a 30m long, two-core mains cable if the conductor material is aluminum and its diameter is 2.5mm? ($\rho_{\text{AL}} = \frac{\Omega \text{mm}^2}{\text{m}}$)? ($R=0.3422\Omega$)

3.6 From a material with what specific resistivity is a heating wire made if it has a resistance of 75Ω , a diameter of 1mm, and a length of 15 m? ($3.9 \frac{\Omega \text{mm}^2}{\text{m}}$)

4. CABLE SIZING**EXAMPLE**

A current of 2A flows in the winding of a transformer (the winding material is copper). The permissible current density is $J=2.5\text{A}/\text{mm}^2$. Calculate the cross-sectional area of the winding wire.

$$I = 2\text{A}$$

$$J = 2.5\text{A}/\text{mm}^2$$

$$A = ?$$

$$J = \frac{I}{A} \rightarrow A = \frac{I}{J} = \frac{2\text{A}}{2.5\text{A}/\text{mm}^2} = 0.8\text{mm}^2$$

PROBLEMS

4.1 A current of 2A flows in the winding of a transformer (the winding material is copper). The permissible current density is $J=2.5\text{A/mm}^2$. Calculate the cross-sectional area of the winding wire (0.8mm^2).

4.2 The length of a cable is 30m, its cross-sectional area is 1.5mm^2 , and the material is copper ($\rho_{copper} = 0,0175 \frac{\Omega\text{mm}^2}{\text{m}}$).

a. Calculate the current that can flow through the conductor if the permissible current density is $J=2.5\text{A/mm}^2$ (3.75A).

b. What is the voltage drop when the load is at its maximum (1,31V)?

4.3 Calculate the diameter of the wire to be used for connecting an oven if the permissible current density is $J=10\text{A/mm}^2$ and the load current is 15A! ($1,5\text{mm}^2$)

4.4 Calculate the required cross-sectional area of a conductor if we want to operate a 3450W, 230V mains-powered load, with a maximum voltage drop of 2%. The load is 25m from the supply point, and the conductor material is copper. ($\rho_{copper} = 0.0175 \frac{\Omega\text{mm}^2}{\text{m}}$)! (1.42mm^2)

4.5 A loudspeaker coil is made from copper wire with a diameter of 0.8mm. The winding length is 7.5m. What is the maximum current if the permissible current density is $J=2.5\text{A/mm}^2$? ($\rho_{copper} = 0.0175 \frac{\Omega\text{mm}^2}{\text{m}}$). (1.255A)

4.6 What will be the voltage drop on a 50m long copper cable if the conductor has a cross-sectional area of 6mm^2 and carries a current of 25A ($\rho_{copper} = 0,0175 \frac{\Omega\text{mm}^2}{\text{m}}$)? (3,645V)

5. TEMPERATURE DEPENDENCE OF RESISTANCE

EXAMPLE

An aluminum wire lighting network has a resistance of 15Ω at 20°C . What will its resistance be if, due to the load, its temperature rises to 54°C ? $\alpha_{\text{AL}} = 0,00377 \text{ } 1/^\circ\text{C}$.

$$R_{20} = 15\Omega$$

$$T_a = 20^\circ\text{C}$$

$$T_m = 54^\circ\text{C}$$

$$\alpha_{\text{AL}} = 0.00377 \text{ } 1/^\circ\text{C}$$

$$R_{54^\circ\text{C}} = ?$$

$$R_{54^\circ\text{C}} = R_{20^\circ\text{C}}(1 + \alpha\Delta T) = 15\Omega(1 + 0.00377 \text{ } 1/^\circ\text{C} \cdot 54^\circ\text{C} - 20^\circ\text{C}) = 16.9227\Omega$$

FELADATOK

5.1 Calculate the increase in the DC resistance of a coil if its temperature rises from 0°C to 55°C . The coil's resistance at 0°C is 100Ω . The temperature coefficient is $\alpha_{\text{CU}} = 0,0038 \text{ } 1/^\circ\text{C}$. ($\Delta R=20,9\Omega$)

5.2 An aluminum wire lighting network has a resistance of 15Ω at 20°C . What will its resistance be if, due to the load, its temperature rises to 54°C ? The temperature coefficient is $\alpha_{\text{AL}} = 0.00377$ $1/^\circ\text{C}$. ($R=16.9227\Omega$)

5.3 The resistance of a copper coil of an electromagnet is 120Ω at 20°C . What will its resistance be during operation at 75°C ? The temperature coefficient is $\alpha_{\text{CU}} = 0.00393$ $1/^\circ\text{C}$ ($R=145.938\Omega$)

5.4 A 40W incandescent lamp's tungsten filament has a resistance of 120Ω at operating temperature and a cold resistance of 97.5Ω at 20°C . What is the filament's operating temperature? The temperature coefficient is $\alpha_{\text{WOLF}} = 0.004$ $1/^\circ\text{C}$ (77.69°C)

6. OHM'S LAW

EXAMPLE

What current flows through a water heater (boiler) if it is connected to 230V and the heating element has a resistance of 50Ω ?

$$U = 230V$$

$$R = 50\Omega$$

$$I = ?$$

$$R = \frac{U}{I} \rightarrow I = \frac{U}{R} = \frac{230V}{50\Omega} = 4.6A$$

PROBLEMS:

6.1 The following table is given. Calculate the missing values! Plot the current-voltage characteristic!

I [mA]	1	2	5	10	20
U [V]		8			

6.2 What is the resistance of a water heater through which a current of 4.5A flows when connected to a 230V mains voltage? (51.1Ω)

6.3 What is the resistance of the winding if a current of 180A flows through it and the voltage drop across the wire is 950V? (5.27Ω)

6.4 What current flows through a $0.75\text{k}\Omega$ resistor when it is connected to a 3.5V voltage? (4.66mA)

6.5 What current flows through a water heater (boiler) if it is connected to 230V and the heating element has a resistance of 50Ω ? ($4.6A$)

6.6 What current flows in the main conductor of a five-branch chandelier if each bulb has a voltage of 230V and a resistance of 950Ω each? ($1.21A$)

6.7 A soldering iron has a rated voltage of 24V and a current of 1.8A. Calculate the current if its operating voltage changes by +10% or -20%! ($I_{+10}=1,97\text{A}$; $I_{-20}=1,439\text{A}$)

6.8 A space heater has a current of 5.1A. At the mains plug, 224V is measured, and across the appliance terminals 212V is measured between the two wires. What is the resistance of the wire pair? ($R=2.35\Omega$)

6.9 On a 4mm^2 cross-section aluminum conductor, the permissible current is 35A. What will be the voltage drop across it if it is 100m long? ($\rho_{AL} = 0.02867 \frac{\Omega\text{mm}^2}{\text{m}}$) (25.086V)

6.10 A 6V battery powers a load drawing 3A. What distance can the load be from the battery if the 1.5mm^2 cross-section aluminum conductor allows a maximum voltage drop of 2.5%?

$$\left(\rho_{AL} = 0.02867 \frac{\Omega\text{mm}^2}{\text{m}}\right) (2.615\text{m})$$

7. WORK, POWER, EFFICIENCY

EXAMPLE

A resistor has the following markings: 470Ω , 2W. What current can flow through the resistor, and what voltage will drop across it?

$$R = 470\Omega$$

$$P = 2\text{W}$$

$$I = ?$$

$$P = I^2 R \rightarrow I = \sqrt{\frac{P}{R}} = \sqrt{\frac{2\text{W}}{470\Omega}} = 65.232\text{mA}$$

$$R = \frac{U}{I} \rightarrow U = IR = 65.232\text{mA} \cdot 470\Omega = 30.659\text{V}$$

PROBLEMS

7.1 A 800W vacuum cleaner has an efficiency of 80%. What are the useful and loss powers? ($P_u = 640\text{W}$, $P_l=160\text{W}$)

7.2 How much energy is saved in a year if five 75W bulbs in a chandelier are replaced with 60W bulbs, operating on average 4.5 hours per day? (123.19kWh)

7.3 A resistor has the following markings: 470Ω , 2W. What current can flow through the resistor, and what voltage will drop across it? (65.232mA; 30.659V)

7.4 A 45W car headlight operates at 12V. What is its operating resistance and current? How much energy does it consume in 2 hours? ($R=3.2\Omega$; $I=3.75\text{A}$; $W=90\text{Wh}$)

7.5 What is the resistance of a 24V, 45W soldering iron? ($R=12.8\Omega$)

7.6 A 12V battery is charged with a generator at $U_0 = 13.7V$. The charging current is constant. The resistor setting the current has a value of $R = 0.31\Omega$

- What power is converted to heat in the resistor? ($P = 9,32W$)
- How much energy does the charger deliver during a 12-hour charge? ($W = 0,9015kWh$)
- What is the efficiency of the battery charger? ($87,59\%$)

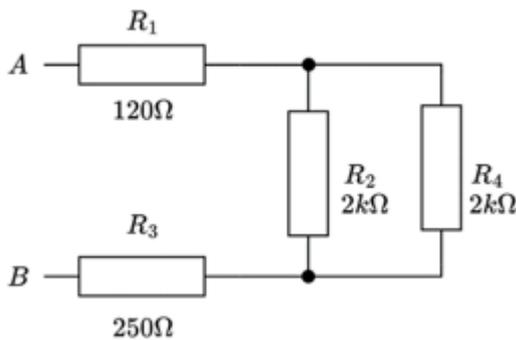
7.7 A car's electrical system is 12V. The windshield wiper motor has a rated power of 50W. What is the rated current of the motor? Assuming continuous operation, how much electrical energy does it consume in half an hour? What percentage of a fully charged 55Ah battery is lost during this time? ($I = 4.167A$; $W = 25Wh$; 3.78%)

7.8 A car starter has a power of 1.5 kW, and the battery's nominal voltage is 12V. The battery can provide a total of 60Ah. What percentage of the battery's charge is consumed by using the starter for 12 seconds? (0.69%)

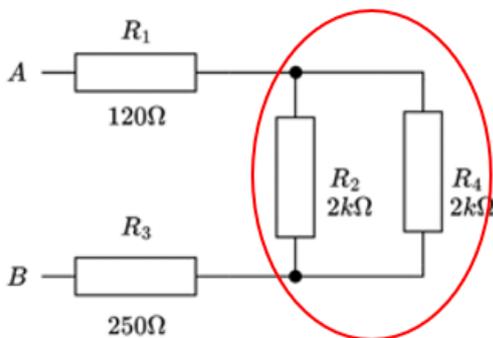
8. CALCULATION OF EQUIVALENT RESISTANCE

8.1 Calculate the equivalent resistance of the network between points A and B based on the given resistor values!

MINTAPÉLDA

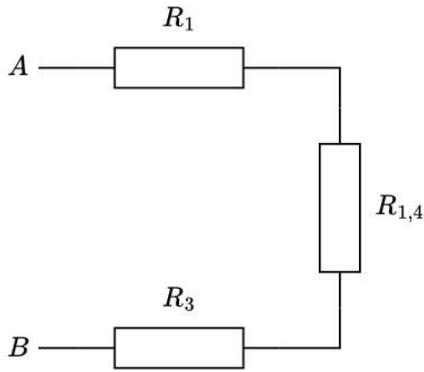


The task always begins by identifying two or more resistors that are in series or parallel! Always proceed **toward the points where the resistance is to be measured** (here, toward RAB).



R_2 and R_4 form a parallel connection, therefore:

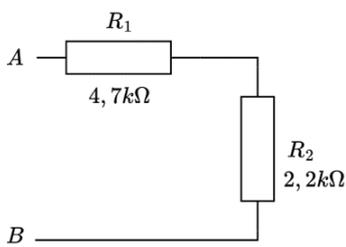
$$R_{2,4} = \frac{R_2 \cdot R_4}{R_2 + R_4} = \frac{2k\Omega \cdot 2k\Omega}{2k\Omega + 2k\Omega} = 1k\Omega$$



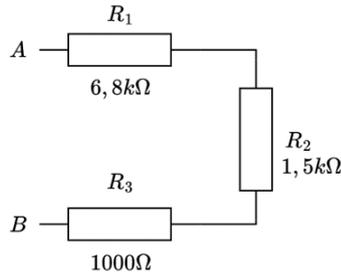
R_1 , R_3 and the previously calculated equivalent resistor together form a series connection, therefore:

$$R_{AB} = R_1 + R_3 + R_{1,4} = 120\Omega + 250\Omega + 1k\Omega = 1370\Omega$$

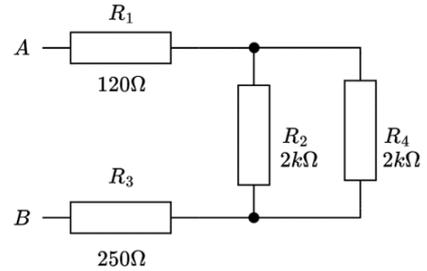
PROBLEMS



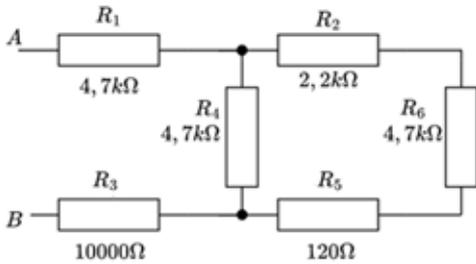
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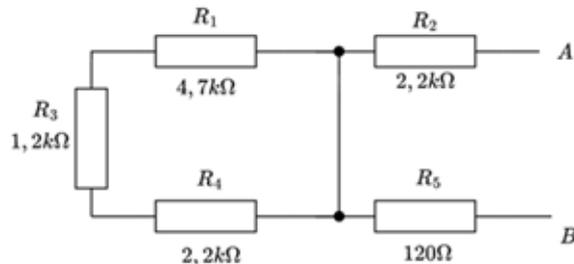
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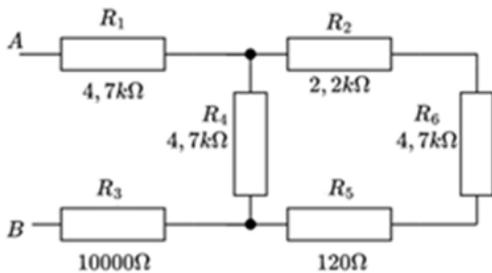
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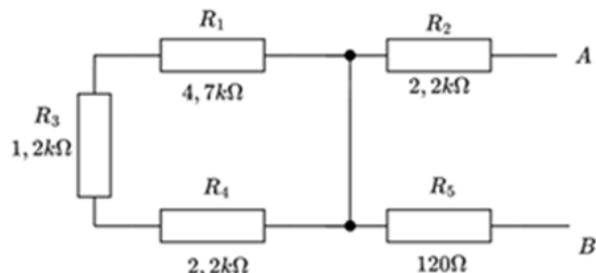
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e.

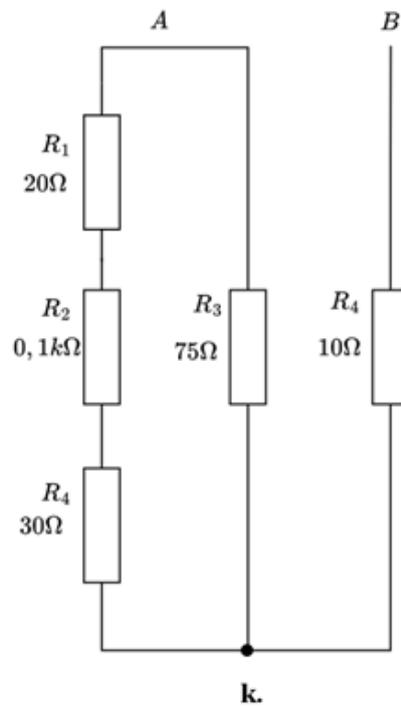
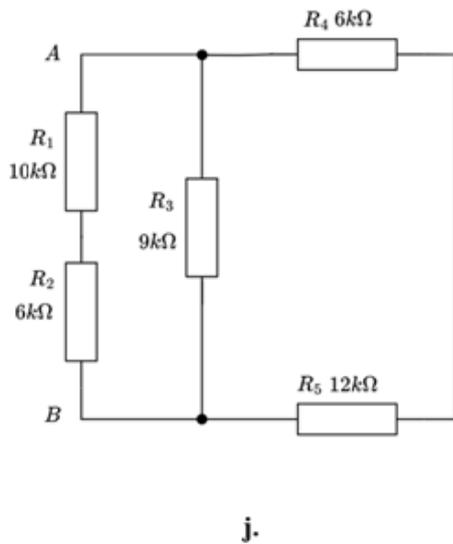
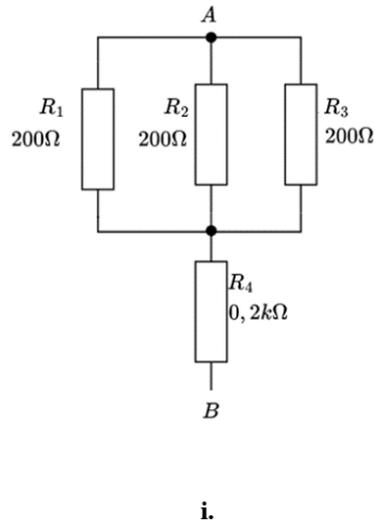
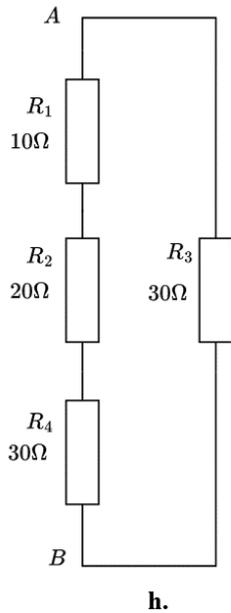
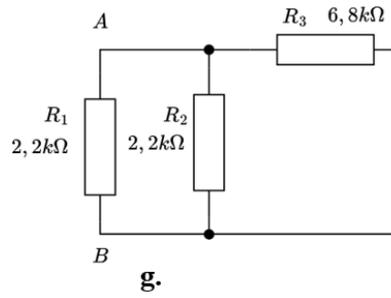
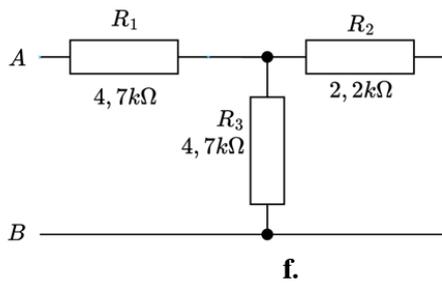


d.



e.

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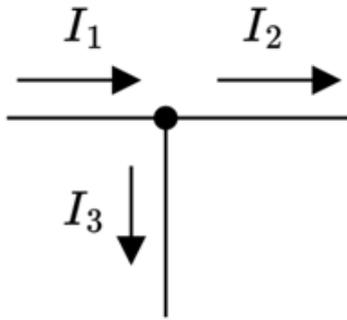


SOLUTIONS:

a. $6.9\text{k}\Omega$; b. $9.3\text{k}\Omega$; c. $1.37\text{k}\Omega$; d. $17.51\text{k}\Omega$; e. $2.32\text{k}\Omega$; f. $9.4\text{k}\Omega$; g. $1.1\text{k}\Omega$; h. 20Ω ; i. 266.67Ω ; j. $4.36\text{k}\Omega$; k. 60Ω

9. SIMPLE APPLICATIONS OF KIRCHHOFF'S LAWS

EXAMPLE

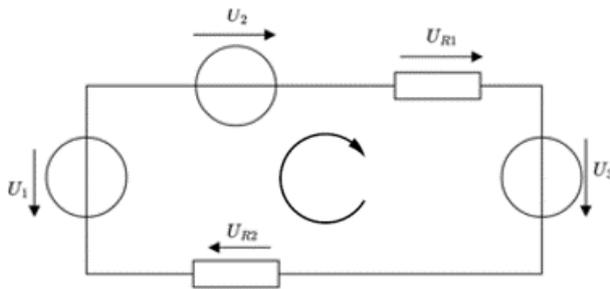


According to Kirchhoff's law:

$$-I_1 + I_2 + I_3 = 0$$

If $I_1 = 10A$; $I_2 = 250mA$, then:

$$I_3 = I_1 - I_2 = 10A - 250mA = 9.75A$$



According to Kirchhoff's law:

$$-U_1 + U_2 + U_{R1} + U_3 + U_{R2} = 0$$

If, $U_1 = 44V$; $U_2 = 0.01kV$;
 $U_3 = 12V$; $U_{R1} = 24V$, then:

$$\begin{aligned} U_{R2} &= U_1 - U_2 - U_{R1} - U_3 \\ &= 44V - 0,01kV \\ &\quad - 24V - 12V \\ &= -2V \end{aligned}$$

PROBLEMS

9.1 Calculate the values of the unknown currents (and, if necessary, their directions) by applying Kirchhoff's current law, given the following data!

Fig. a $I_1 = 10A$; $I_2 = 250mA$

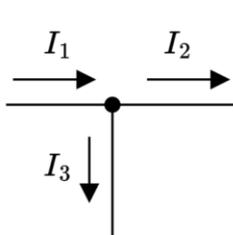
$I_2 = 2.4A$; $I_3 = 1A$

Fig. b $I_1 = 10A$; $I_2 = 250mA$; $I_3 = 4750mA$

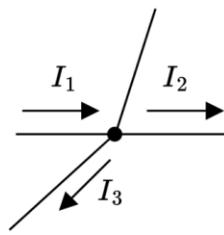
$I_1 = 0.5A$; $I_2 = 375mA$; $I_3 = 75mA$

Fig c. $I_1 = 97mA$; $I_2 = 375mA$; $I_3 = 1.2A$; $I_4 = 120mA$

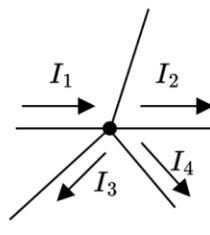
$I_1 = 1200\mu A$; $I_2 = 7.5mA$; $I_3 = 450\mu A$; $I_4 = 15mA$



a.



b.



c.

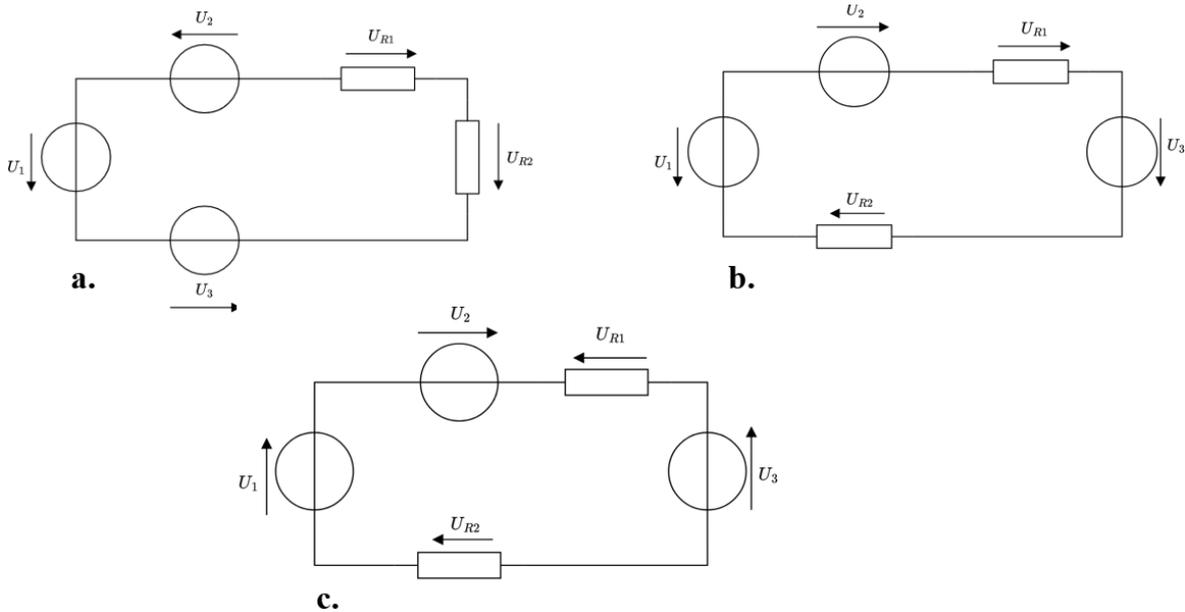
9.2 Calculate the values of the unknown voltages using Kirchhoff's voltage law, given the following data:

Fig. a. $U_1=100\text{V}$; $U_3=75\text{V}$; $U_{R1}=12\text{V}$; $U_{R2}=1.5\text{V}$

Fig. b. $U_1=44\text{V}$; $U_2=0.01\text{kV}$; $U_3=12\text{V}$; $U_{R1}=24\text{V}$

Fig. c. $U_2=0.001\text{kV}$; $U_3=0.5\text{V}$; $U_{R1}=0.75\text{V}$; $U_{R2}=2.5\text{V}$

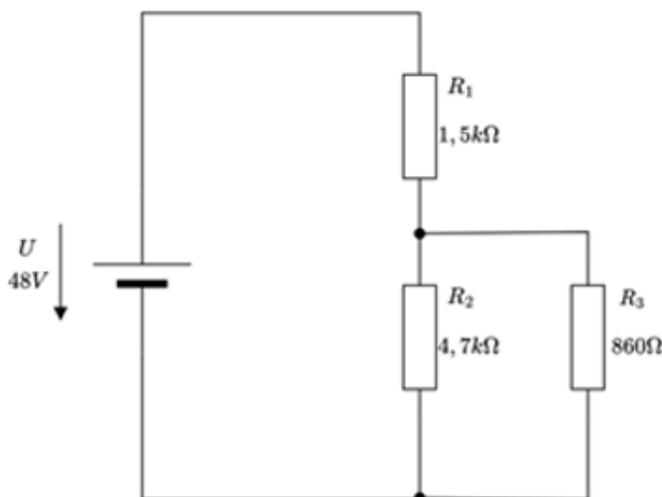
Repeat the calculations by defining the opposite loop direction!



10. VOLTAGE AND CURRENT DISTRIBUTION

10.1 Calculate the voltages across each resistor using the voltage divider rule, based on the given resistor values (including between points A and B in this subtask)!

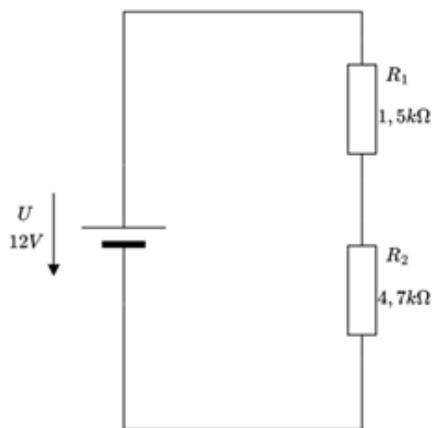
EXAMPLE



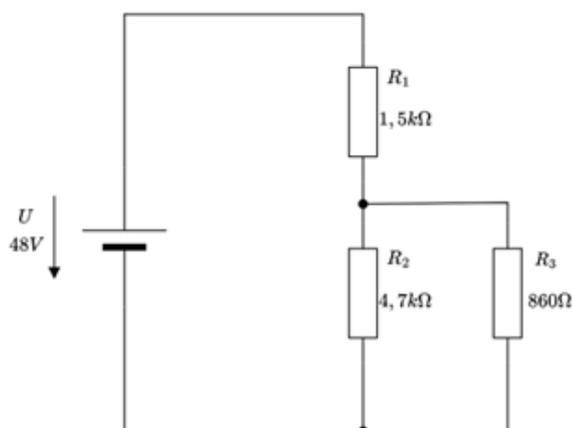
$$\begin{aligned}
 U_{R2} &= U_{R3} = U \frac{R_2 \times R_3}{R_1 + R_2 \times R_3} \\
 &= 48\text{V} \frac{4.7\text{k}\Omega \times 860\Omega}{1.5\text{k}\Omega + 4.7\text{k}\Omega \times 860\Omega} \\
 &= 15.66\text{V}
 \end{aligned}$$

$$\begin{aligned}
 U_{R1} &= U \frac{R_1}{R_1 + R_2 \times R_3} \\
 &= 48\text{V} \frac{1.5\text{k}\Omega}{1.5\text{k}\Omega + 4.7\text{k}\Omega \times 860\Omega} \\
 &= 32.33\text{V}
 \end{aligned}$$

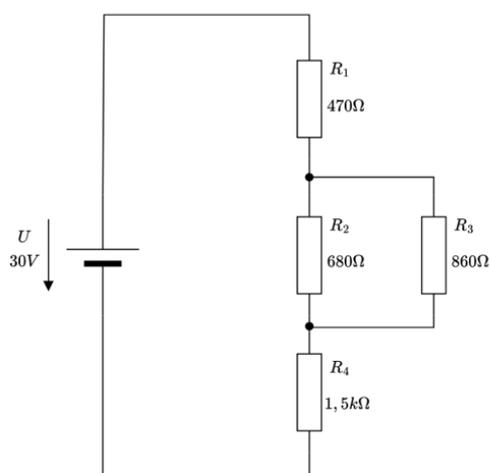
PROBLEMS



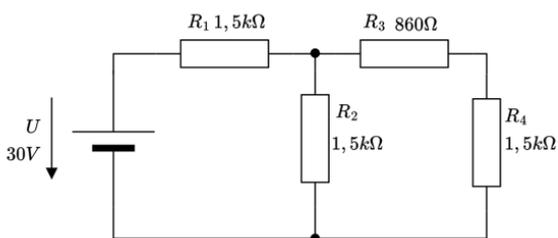
a.



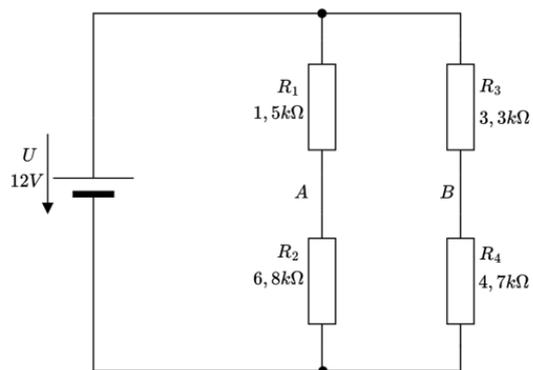
b.



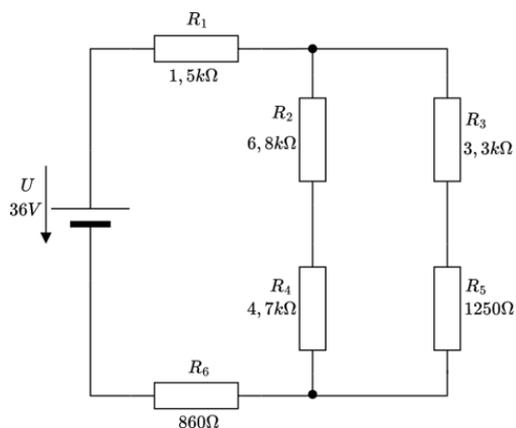
c.



d.



e.



f.

SOLUTIONS:

a. $U_{R1} = 2.9V$; $U_{R2} = 9.09V$

b. $U_{R1} = 32.33V$; $U_{R2} = 15.67V$; $U_{R3} = 15.67V$

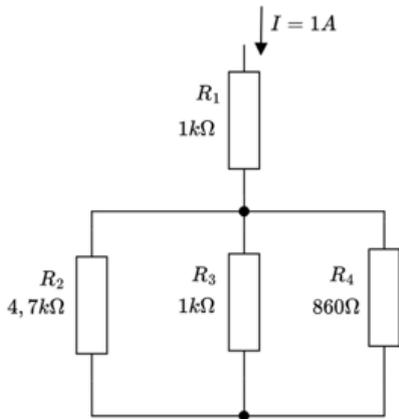
c. $U_{R1} = 6V$; $U_{R2} = 4.84V$; $U_{R3} = 4.84V$; $U_{R4} = 19.16V$

d. $U_{R1} = 18.61V$; $U_{R2} = 11.38V$; $U_{R3} = 4.14V$; $U_{R4} = 7.23V$

e. $U_{R1} = 2.168V$; $U_{R2} = 9.83V$; $U_{R3} = 4.949V$; $U_{R4} = 7.05V$

f. $U_{R1} = 9.6V$; $U_{R2} = 12.34V$; $U_{R3} = 15.14V$; $U_{R4} = 8.53V$; $U_{R5} = 5.73V$; $U_{R6} = 5.5V$

EXAMPLE



Since R_1 is in series with the source current, the current through it is: $I_{R1} = 1A$.

As an example, calculate the current through R_3 !

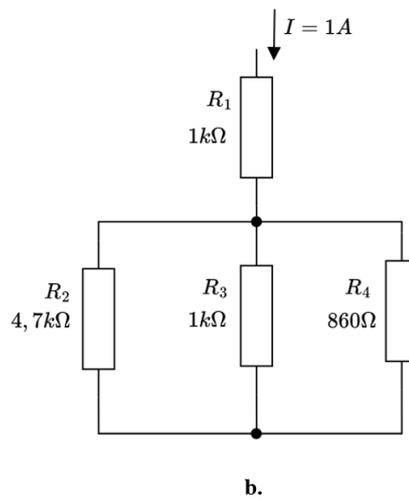
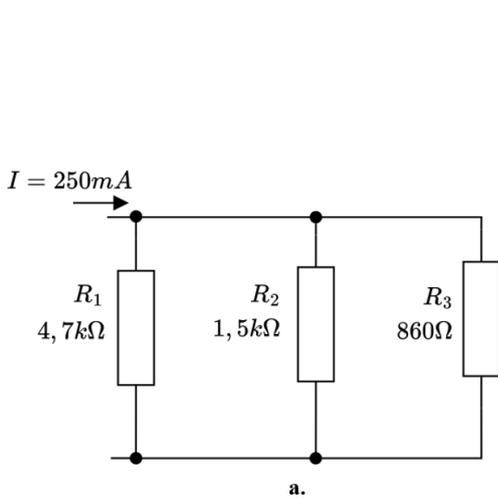
$$I_{R3} = I \frac{R_2 \times R_4}{R_3 + R_2 \times R_4}$$

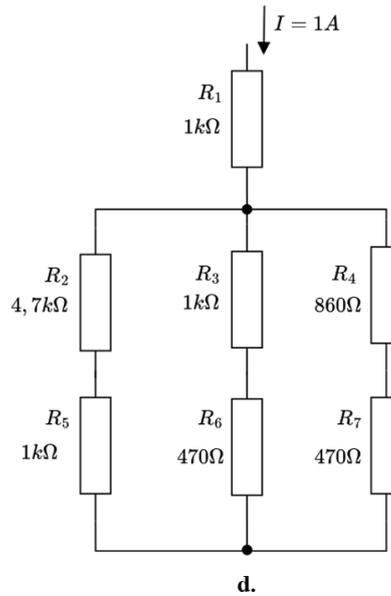
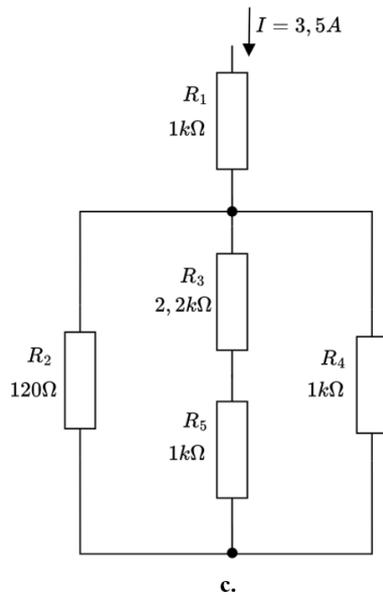
$$= 1A \frac{4.7k\Omega \times 860\Omega}{1k\Omega + 4.7k\Omega \times 860\Omega}$$

$$= 0.42A$$

PROBLEMS

10.2 Calculate the currents through each resistor using the current divider rule, based on the given resistor values!





SOLUTIONS:

a. $I_{R1} = 26.04\text{mA}$; $I_{R2} = 81.6\text{mA}$; $I_{R3} = 142.34\text{mA}$

b. $I_{R1} = 1\text{A}$; $I_{R2} = 89.56\text{mA}$; $I_{R3} = 420.95\text{mA}$; $I_{R4} = 489.48\text{mA}$

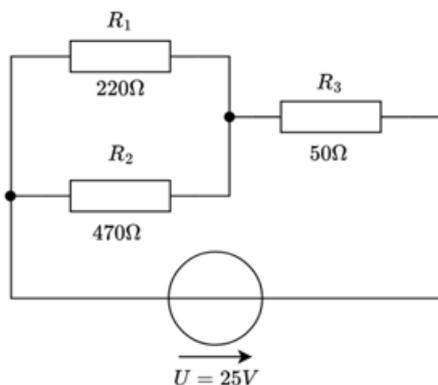
c. $I_{R1} = 3.5\text{A}$; $I_{R2} = 3.02\text{A}$; $I_{R3} = 113.39\text{mA}$; $I_{R4} = 362.85\text{mA}$; $I_{R5} = 113.39\text{mA}$

d. $I_{R1} = 1\text{A}$; $I_{R2} = 109.13\text{mA}$; $I_{R3} = 423.16\text{mA}$; $I_{R4} = 467.7\text{mA}$; $I_{R5} = 109.13\text{mA}$; $I_{R6} = 423.16\text{mA}$; $I_{R7} = 467.7\text{mA}$

11. EXAMINATION OF COMPLEX ELECTRICAL NETWORKS USING OHM'S LAW, CURRENT DIVISION AND VOLTAGE DIVISION

11.1 Calculate, for the given circuits, the load resistance at the generator terminals, as well as the currents through each component, the voltages across them, and the power dissipated on them! Summarize your results in a table. As practice, try solving the tasks using multiple methods and compare the results!

MINTAPÉLDA



The equivalent resistance of the circuit as seen from the generator terminals:

$$R_e = R_3 + R_1 \times R_2 = 50\Omega + 220\Omega \times 470\Omega = 50\Omega + 149.855\Omega = 199.86\Omega$$

The total current (which is equal to the current through R3):

$$I_e = I_{R3} = \frac{U}{R_e} = \frac{25\text{V}}{199.86\Omega} = 0.125\text{A}$$

The voltage across R3:

$$U_{R3} = I_{R3} \cdot R_3 = 0.125\text{A} \cdot 50\Omega = 6.25\text{V}$$

The voltages across R_1 and R_2 are the same (since they form a parallel connection). This voltage can be calculated in several ways; here, we will use Kirchhoff's law:

$$U_{R_1} = U_{R_2} = U - U_{R_3} = 25V - 6.25V = 18.75V$$

The current through R_1 :

$$I_{R_1} = \frac{U_{R_1}}{R_1} = \frac{18.75V}{220\Omega} = 85.23mA$$

The current through R_2 :

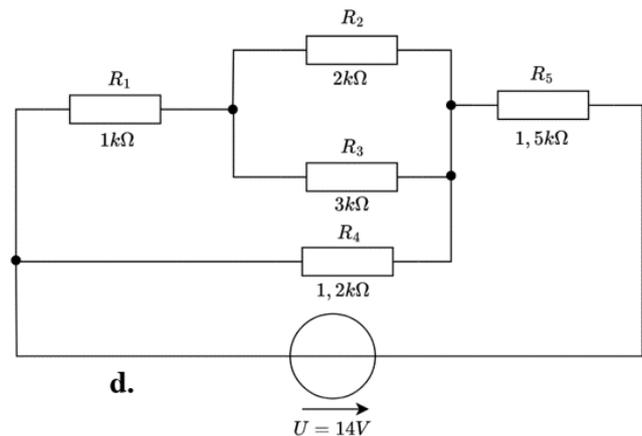
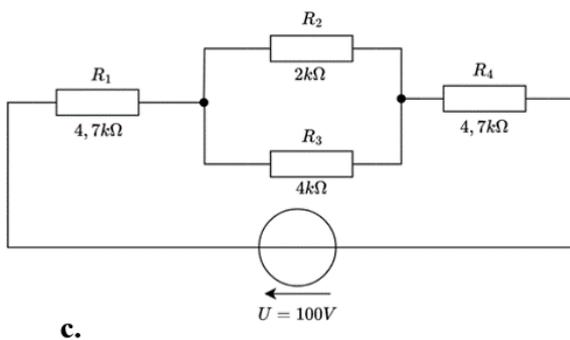
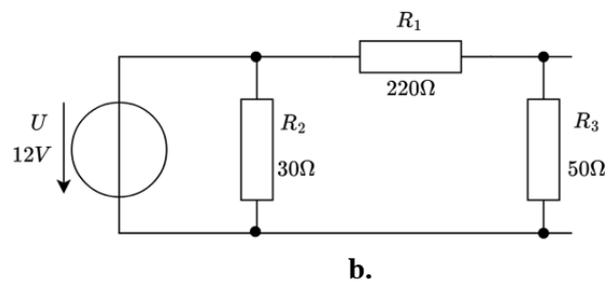
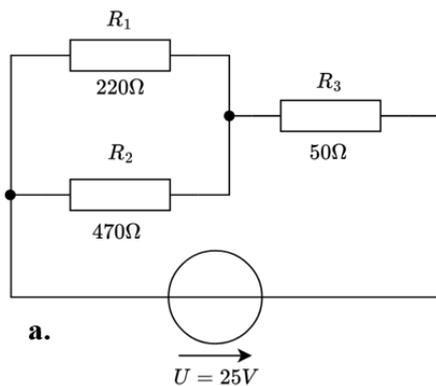
$$I_{R_2} = \frac{U_{R_2}}{R_2} = \frac{18.75V}{470\Omega} = 39.89mA$$

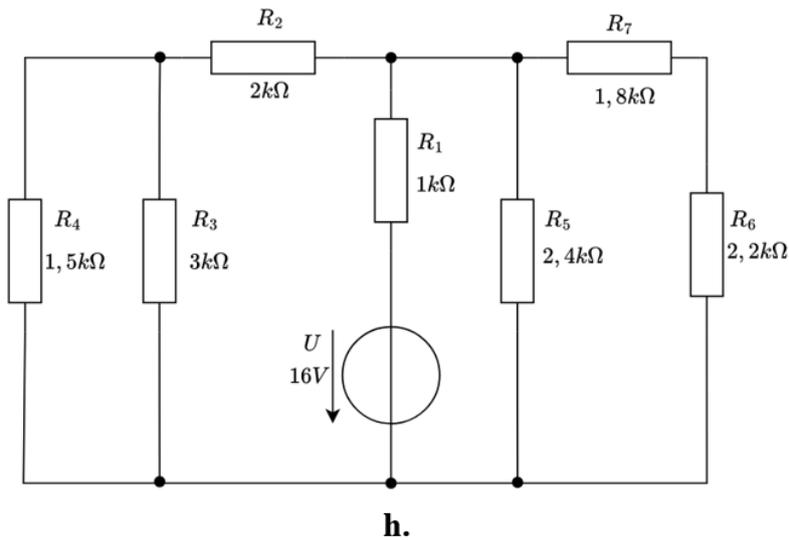
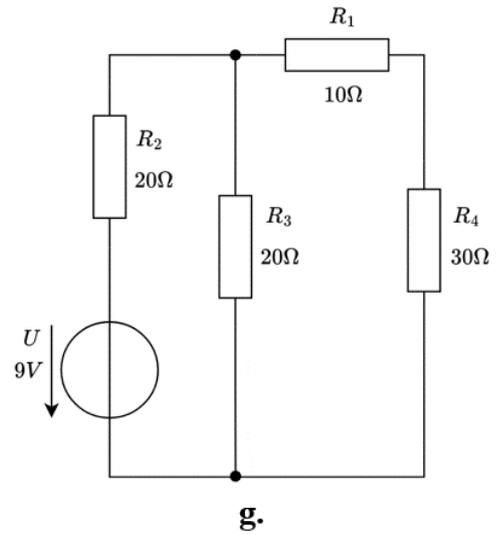
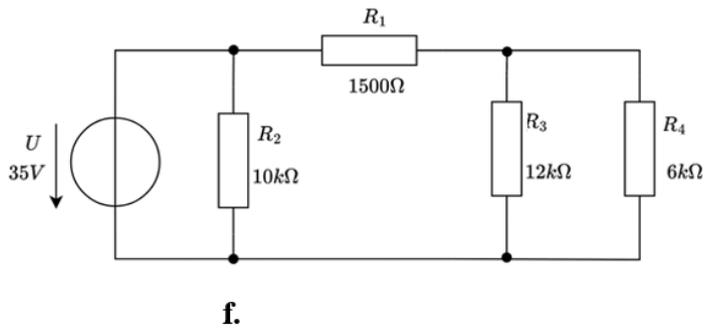
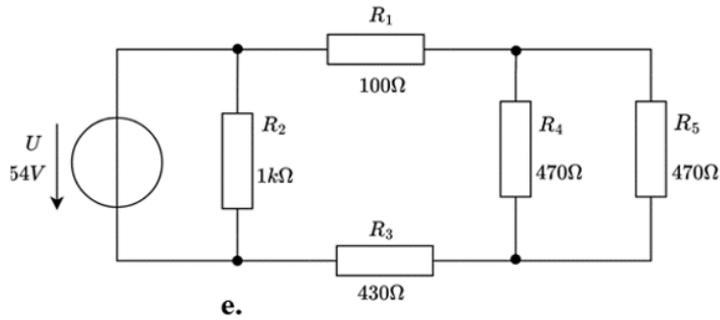
Check:

$$I_{R_1} + I_{R_2} = 85.23mA + 39.89mA = 125.12mA$$

Taking rounding into account, the calculation is correct.

PROBLEMS





SOLUTIONS:

a. $U_{R1} = 18.745V$; $I_{R1} = 85.2mA$; $U_{R2} = 18.745V$; $I_{R2} = 39.88mA$; $U_{R3} = 6.25V$; $I_{R3} = 125.09mA$; $R_e = 199.85\Omega$

b. $U_{R1} = 9.77V$; $I_{R1} = 44.44mA$; $U_{R2} = 12V$; $I_{R2} = 400mA$; $U_{R3} = 2.22V$; $I_{R3} = 44.44mA$; $R_e = 27\Omega$

c. $U_{R1} = 43.78V$; $I_{R1} = 9.31mA$; $U_{R2} = 12.42V$; $I_{R2} = 6.21mA$; $U_{R3} = 12.42V$; $I_{R3} = 3.1mA$; $U_{R4} = 43.78V$; $I_{R4} = 9.31mA$; $R_e = 10.73k\Omega$

d. $U_{R1} = 2.17V$; $I_{R1} = 2.17mA$; $U_{R2} = 2.6V$; $I_{R2} = 1.3mA$; $U_{R3} = 2.6V$; $I_{R3} = 868\mu A$; $U_{R4} = 4.77V$; $I_{R4} = 3.97mA$; $U_{R5} = 9.22V$; $I_{R5} = 6.15mA$; $R_e = 2.28k\Omega$

e. $U_{R1} = 7.058V$; $I_{R1} = 70.58mA$; $U_{R2} = 54V$; $I_{R2} = 54mA$; $U_{R3} = 30.35V$; $I_{R3} = 70.58mA$; $U_{R4} = 16.58V$; $I_{R4} = 35.29mA$; $U_{R5} = 16.58V$; $I_{R5} = 35.29mA$; $R_e = 433.42\Omega$

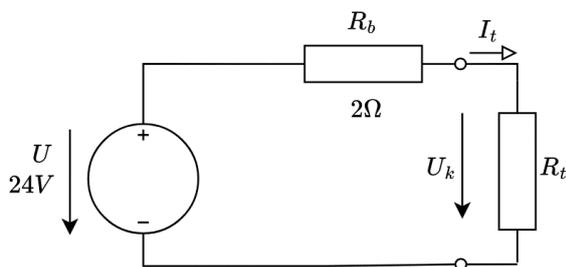
f. $U_{R1} = 9.54V$; $I_{R1} = 6.36mA$; $U_{R2} = 35V$; $I_{R2} = 3.5mA$; $U_{R3} = 25.45V$; $I_{R3} = 2.12mA$; $U_{R4} = 25.45V$; $I_{R4} = 4.24mA$; $R_e = 3.54k\Omega$

g. $U_{R1} = 0.9V$; $I_{R1} = 90mA$; $U_{R2} = 5.4V$; $I_{R2} = 270mA$; $U_{R3} = 3.59V$; $I_{R3} = 180mA$; $U_{R4} = 2.7V$; $I_{R4} = 90mA$; $R_e = 33.34\Omega$

h. $U_{R1} = 8V$; $I_{R1} = 8mA$; $U_{R2} = 5.33V$; $I_{R2} = 2.66mA$; $U_{R3} = 2.66V$; $I_{R3} = 888\mu A$; $U_{R4} = 2.66V$; $I_{R4} = 1.78mA$; $U_{R5} = 8V$; $I_{R5} = 3.33mA$; $U_{R6} = 4.4V$; $I_{R6} = 2mA$; $U_{R7} = 3.59V$; $I_{R7} = 2mA$; $R_e = 2k\Omega$

12. LOADING OF VOLTAGE GENERATORS

EXAMPLE



Calculate, for the circuit shown, the terminal voltage and the load current for load resistances of 0, 1, 2, 3, 4, 6 ... 24Ω.

For $R_t = 0\Omega$ (i.e., in the case of a short-circuited output):

$$U_k = 0V$$

For $R_t = 1\Omega$:

$$U_k = U \frac{R_t}{R_t + R_b} = 24V \frac{1\Omega}{1\Omega + 2\Omega} = 8V$$

For $R_t = 2\Omega$:

$$U_k = U \frac{R_t}{R_t + R_b} = 24V \frac{2\Omega}{2\Omega + 2\Omega} = 12V$$

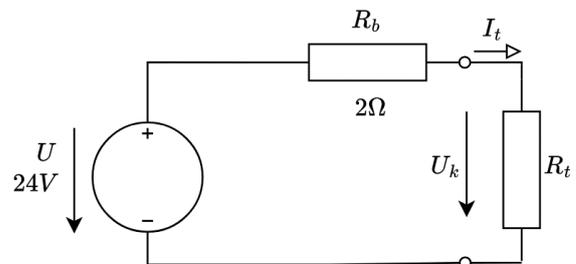
For $R_t = 4\Omega$:

$$U_k = U \frac{R_t}{R_t + R_b} = 24V \frac{4\Omega}{4\Omega + 2\Omega} = 16V$$

What trend can be observed?

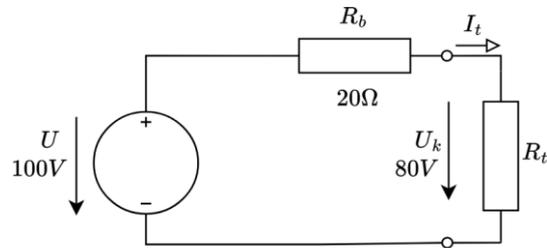
PROBLEMS

12.1 Calculate the terminal voltage and the load current in the circuit shown for load resistances of 0, 1, 2, 3, 4, 6 ... 24Ω. Compile the calculated data into a table and plot the changes of these characteristics versus the load on a properly scaled graph!

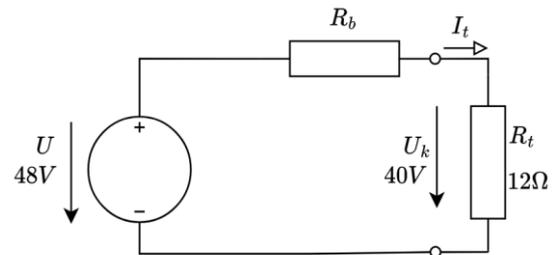


12.2 A 25V source voltage, 5Ω internal resistance voltage generator is connected to a 15Ω load. Calculate the generator terminal voltage and the current through the load! Draw the circuit diagram! ($U_k = 18.75V$; $I_t = 1.25A$)

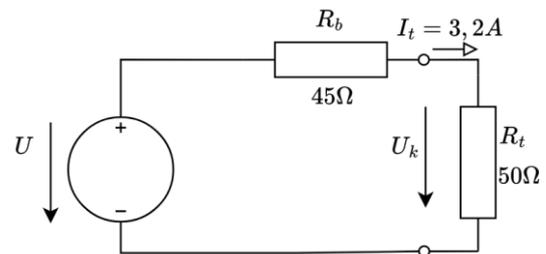
12.3 Calculate, for the given circuit, the load resistance as well as the load current! ($R_t = 80\Omega$. $I_t = 1A$)



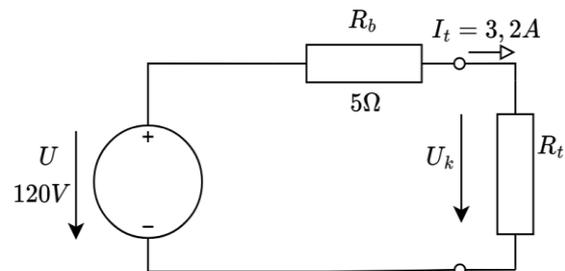
12.4 Calculate, for the given circuit, the load resistance as well as the load current! ($I_t = 3.33A$; $R_b = 2.4\Omega$)

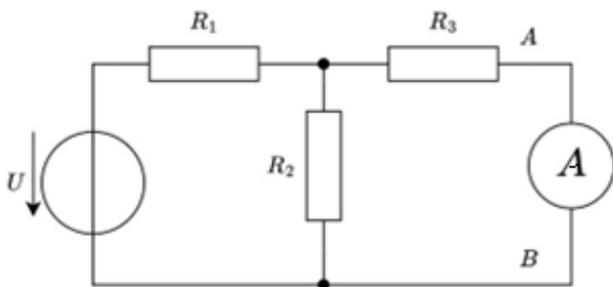
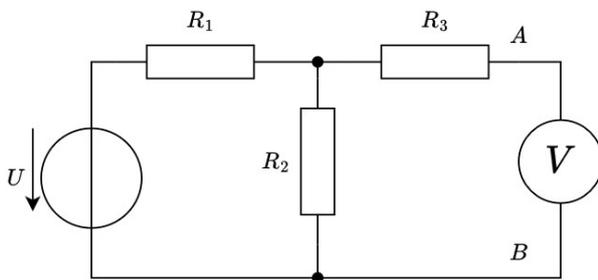
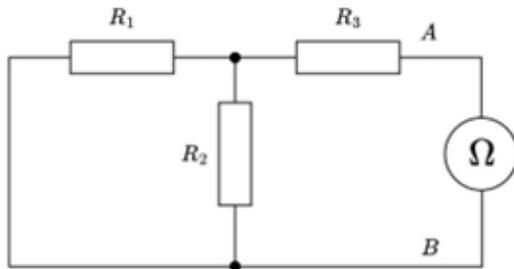
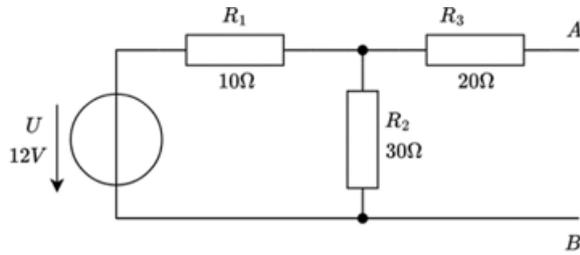


12.5 Calculate, for the given circuit, the generator's source voltage and the terminal voltage! ($U = 304V$ $U_k = 160V$)



12.6 Calculate, for the given circuit, the terminal voltage and the load resistance! ($U_k = 104V$; $R_t = 32.5\Omega$)



13. THEVENIN AND NORTON THEOREMS**EXAMPLE:**

The steps for solving the task are as follows:

1. Determine the load resistance across terminals AB
2. Determine the output current/voltage as a function of the requested equivalent circuit.

To determine the internal resistance, replace the source with a short circuit (since this is a voltage generator). Then connect an ohmmeter to the output (AB) terminals. The resistance referred to the AB terminals is:

$$\begin{aligned} R_{AB} &= R_1 \times R_2 + R_3 \\ &= 10\Omega \times 30\Omega + 20\Omega \\ &= 27.5\Omega \end{aligned}$$

For the Thévenin equivalent circuit, the voltage measurable at the AB terminals is needed. The voltage at the AB terminals is equal to the voltage across R_2 , that is

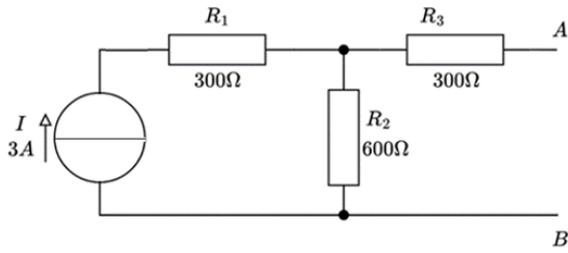
$$\begin{aligned} U_{R_2} &= U \frac{R_2}{R_1 + R_2} = 12V \frac{30\Omega}{10\Omega + 30\Omega} \\ &= 9V \end{aligned}$$

For the Norton equivalent circuit, the current measurable at the AB terminals is needed. The current at the AB terminals is equal to the current through R_3 . Due to the nature of the voltage source, it is more practical to first calculate the voltage across it. That is,

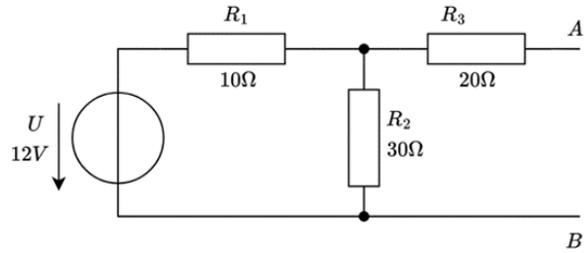
$$\begin{aligned} U_{R_3} &= U \frac{R_2 \times R_3}{R_1 + R_2 \times R_3} = 6,54V \\ I_{R_3} &= \frac{U_{R_3}}{R_3} = \frac{6,54V}{20\Omega} = 327mA \end{aligned}$$

PROBLEMS:

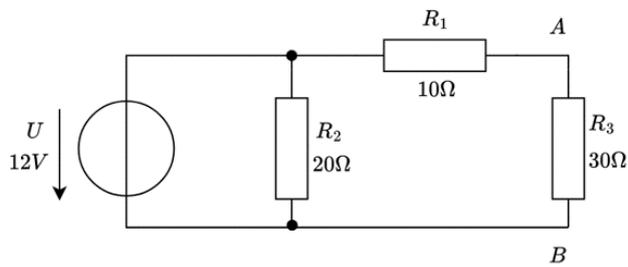
13.1 Determine the Norton and Thévenin equivalent circuits of the circuits shown in the figures (current source, voltage source, internal resistance), and then draw the equivalent circuits!



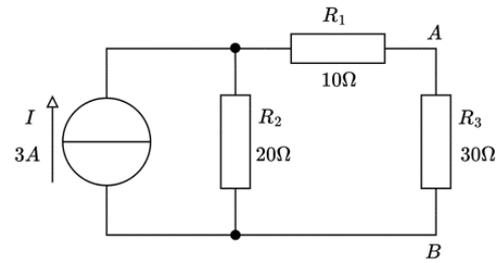
a.



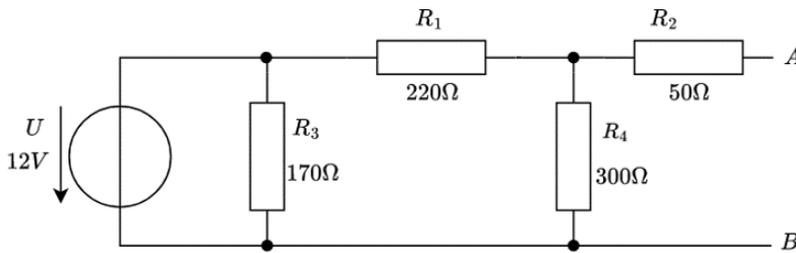
b.



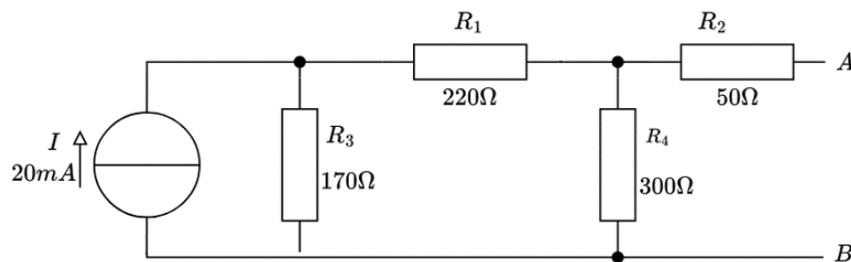
c.



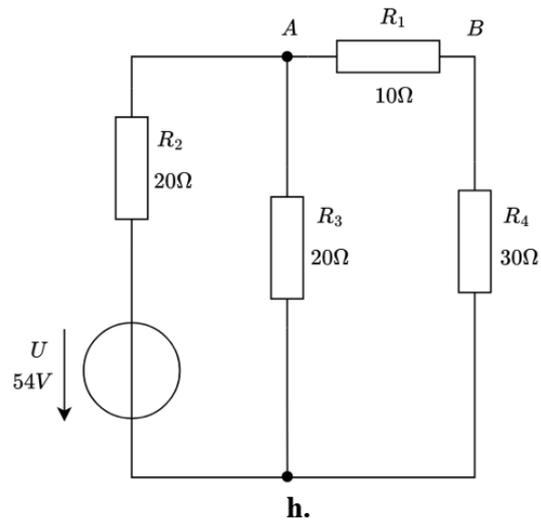
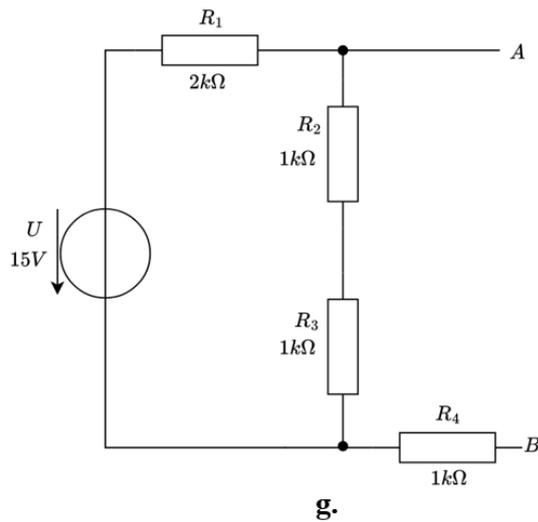
d.



e.



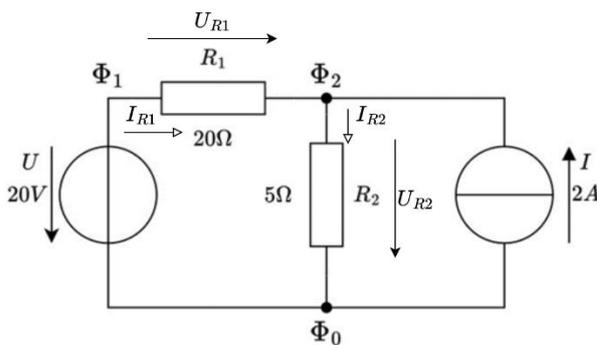
f.



Megoldások: a. $R_{AB}=900\Omega$. $U_{AB}=1800V$. $I_{AB}=2A$; b. $R_{AB}=27.5\Omega$. $U_{AB}=9V$. $I_{AB}=327.27mA$; c. $R_{AB}=7.5\Omega$. $U_{AB}=9V$. $I_{AB}=1.2A$; d. $R_{AB}=15\Omega$. $U_{AB}=30V$. $I_{AB}=2A$; e. $R_{AB}=176.923\Omega$. $U_{AB}=6.923V$. $I_{AB}=39.13mA$; f. $R_{AB}=219.565\Omega$. $U_{AB}=1.478V$. $I_{AB}=6.732mA$; g. $R_{AB}=1k\Omega$. $U_{AB}=7.5V$. $I_{AB}=3.75mA$; h. $R_{AB}=8\Omega$. $U_{AB}=5.4V$. $I_{AB}=0.675A$

14. MULTI-SOURCE NETWORKS

EXAMPLE



When solving using the node voltage method, the following simplifications are applied:

The references (U, I) on the resistors point in the same direction (here, from left to right/top to bottom).

A consistent unit system is used.
The number of unknown nodes is: $n - n_u - 1 = 3 - 1 - 1 = 1$

The only unknown node is Φ_2 , whose equation is the following:

$$\begin{aligned}
 -I - \frac{\Phi_1 - \Phi_2}{R_1} + \frac{\Phi_2}{R_2} &= 0 \\
 -2 - \frac{20 - \Phi_2}{20} + \frac{\Phi_2}{5} &= 0 \\
 -40 - 20 + \Phi_2 + 4\Phi_2 &= 0 \\
 5\Phi_2 &= 60 \\
 \Phi_2 &= 12
 \end{aligned}$$

The voltages across each component, the currents through them, and the measurable power values are as follows:

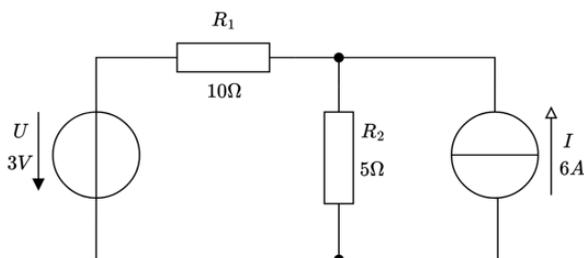
Component	Voltage [U]	Current [I]	Power [P]
R_1	$20 - 12 = 8V$	$\frac{8V}{20\Omega} = 0.4A$	$8V \cdot 0,4A = 3.2W$
R_2	12V	$\frac{12V}{5\Omega} = 2.4A$	$12V \cdot 2,4A = 28.8W$
U	20V	-0.4A*	-8W
I	-12V**	2A	-24W

* The current of the voltage generator is the same as through resistor R_1 , but opposite in direction to the voltage of the voltage generator.

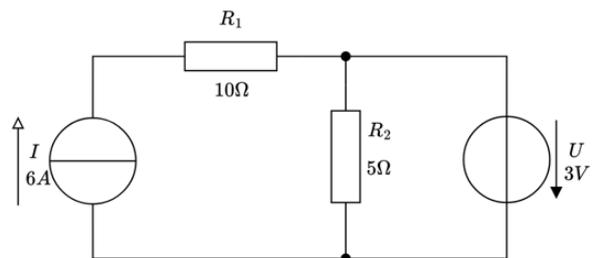
** The current source is connected across the same nodes as R_2 , but in the opposite direction to the current of the current source.

PROBLEMS

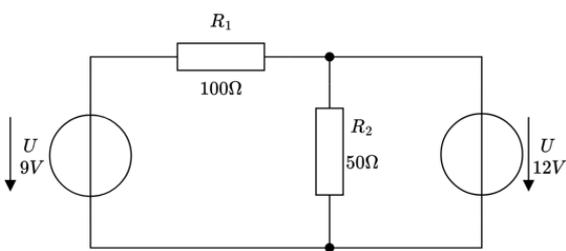
14.1 Determine the voltage, current, and power of every component in the networks given in the task!



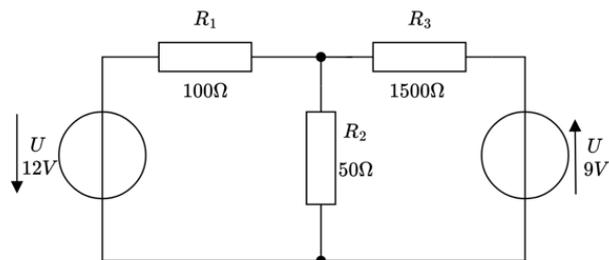
a.



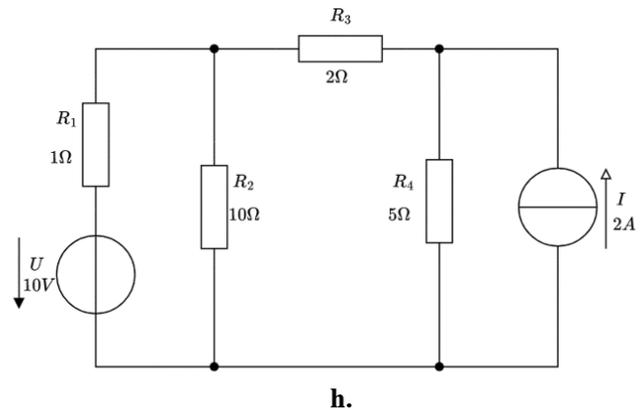
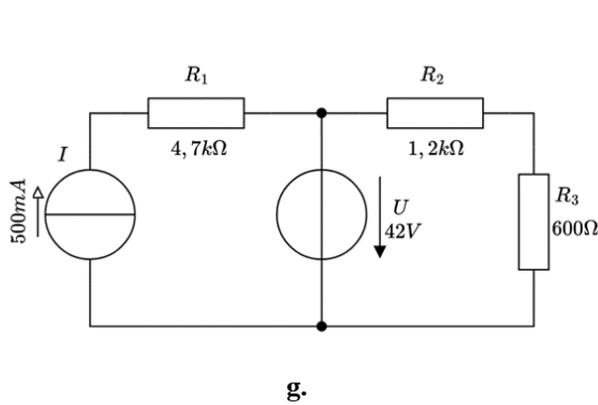
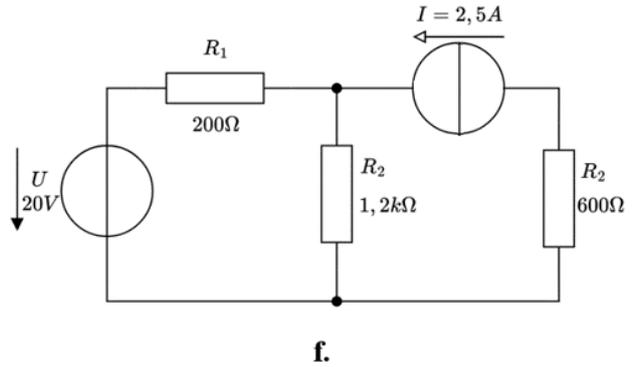
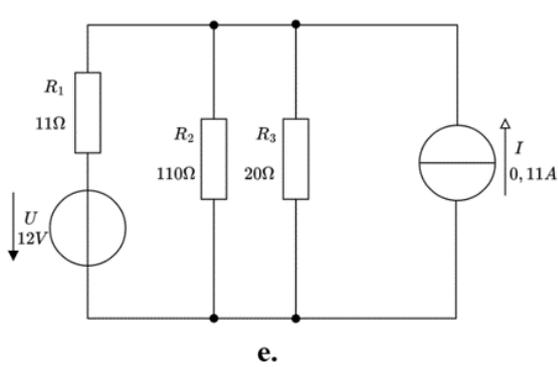
b.



c.



d.

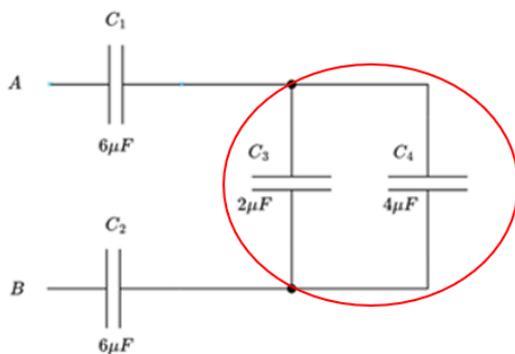


Solutions (only the power values are provided in the solutions, so the tasks can be solved using any method):

- a. $P_{R1} = 32.4\text{W}$; $P_{R2} = 88.2\text{W}$; $P_U = 5.4\text{W}$; $P_I = -126\text{W}$
- b. $P_{R1} = 360\text{W}$; $P_{R2} = 1.8\text{W}$; $P_U = 16.2\text{W}$; $P_I = -378\text{W}$
- c. $P_{R1} = 90\text{mW}$; $P_{R2} = 2.88\text{W}$; $P_{U9\text{V}} = 0.27\text{W}$; $P_{U12\text{V}} = -3.24\text{W}$
- d. $P_{R1} = 687\text{mW}$; $P_{R2} = 275\text{mW}$; $P_{R3} = 107\text{mW}$; $P_{U12\text{V}} = -993\text{mW}$; $P_{U9\text{V}} = -76\text{mW}$
- e. $P_{R1} = 1.45\text{W}$; $P_{R2} = 0.582\text{mW}$; $P_{R3} = 3.2\text{W}$; $P_U = -4.35\text{W}$; $P_I = -0.88\text{W}$
- f. $P_{R1} = 906.15\text{W}$; $P_{R2} = 165.54\text{W}$; $P_{R3} = 3750\text{W}$; $P_U = 42.56\text{W}$; $P_I = -4864\text{W}$
- g. $P_{R1} = 1175\text{W}$; $P_{R2} = 653.24\text{mW}$; $P_{R3} = 327.6\text{mW}$; $P_U = 20\text{W}$; $P_I = -1196\text{W}$
- h. $P_{R1} = 647\text{mW}$; $P_{R2} = 8.45\text{W}$; $P_{R3} = 26.4\text{mW}$; $P_{R4} = 17.76\text{W}$; $P_U = -8.046\text{W}$; $P_I = -18.85\text{W}$

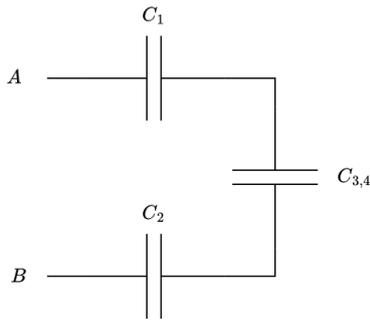
15. ELECTRIC FIELD. CAPACITORS

EXAMPLE



Start the task similarly as with resistors. Identify two or more capacitors that are in series or parallel. Accordingly, C_3 and C_4 form a parallel connection, so their equivalent capacitance is:

$$C_{3,4} = C_3 + C_4 = 2\mu\text{F} + 4\mu\text{F} = 6\mu\text{F}$$



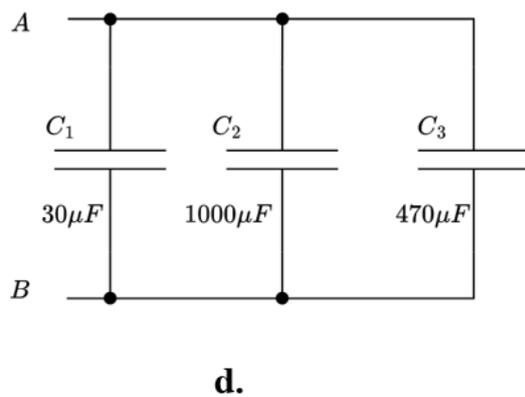
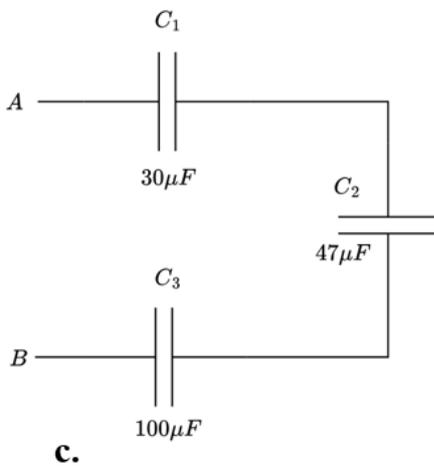
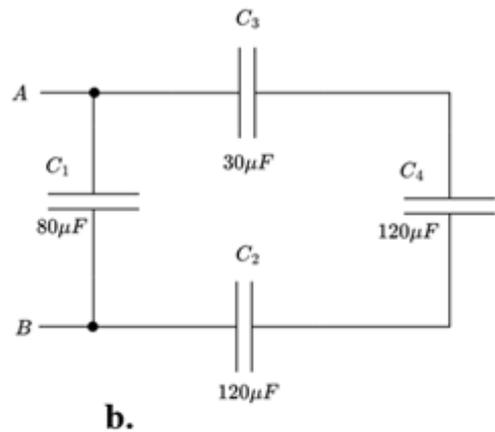
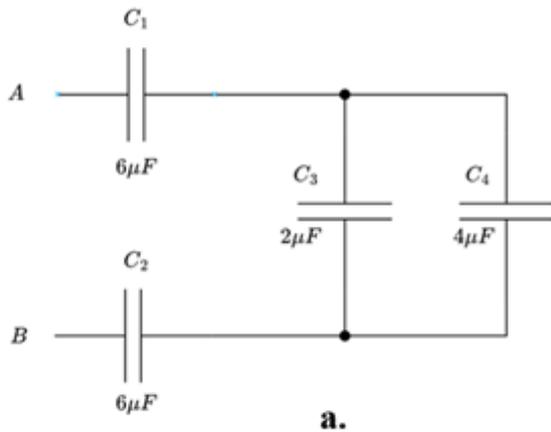
In the resulting network, the three capacitors form a series connection. The equivalent capacitance referred to the AB terminals is:

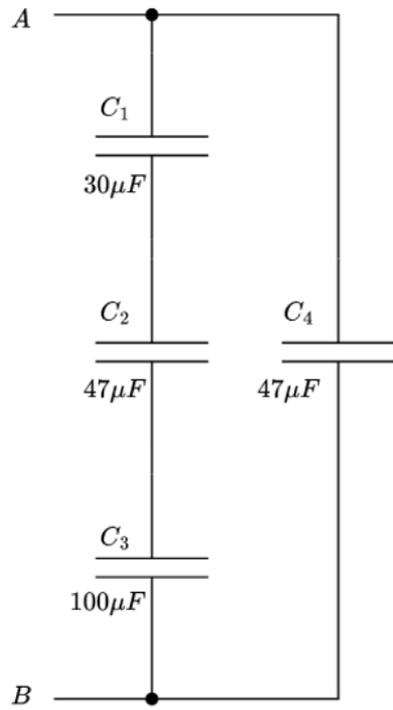
$$C_{AB} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_{3,4}} + \frac{1}{C_2}}$$

$$= \frac{1}{\frac{1}{6\mu F} + \frac{1}{6\mu F} + \frac{1}{6\mu F}}$$

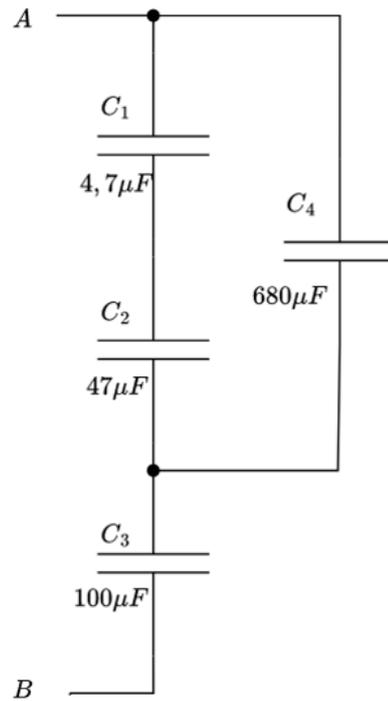
PROBLEMS

- 15.1 What is the capacitance of a capacitor that is charged with 250μC to 320V? (C=781.25nF)
- 15. How much charge accumulates on a 200μF capacitor when a 500V voltage is applied to it? (Q=0.1C)
- 15.3 What is the voltage across a 270nF capacitor that has 310nC of charge on its plates? (U=1.148V)
- 15.4 Calculate the equivalent capacitance between points A and B!





e.

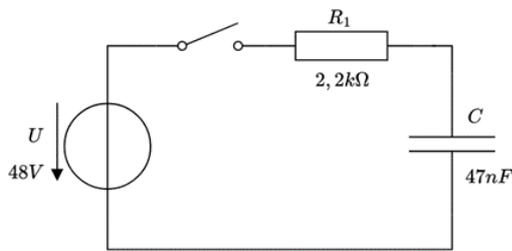


f.

Megoldások: a. $2\mu F$; b. $100\mu F$; c. $15,47\mu F$; d. $1500\mu F$; e. $62,47\mu F$; f. $87,249\mu F$

16. DYNAMIC PHENOMENA

EXAMPLE



Determine the charging current and the voltage and current across the capacitor $70\mu\text{s}$ after switching on!

$$\tau = RC = 2,2k\Omega \cdot 47nF = 103.4\mu\text{s}$$

$$u_{C(70\mu\text{s})} = U \left(1 - e^{-\frac{t}{\tau}} \right) = 48V \left(1 - e^{-\frac{70\mu\text{s}}{103.4\mu\text{s}}} \right) = 23.6V$$

$$i_{C(70\mu\text{s})} = \frac{U - u_{C(70\mu\text{s})}}{R} = \frac{48V - 23.6V}{2.2k\Omega} = 11.09mA$$

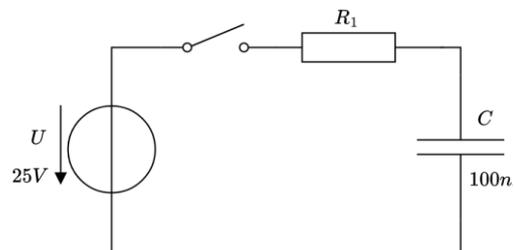
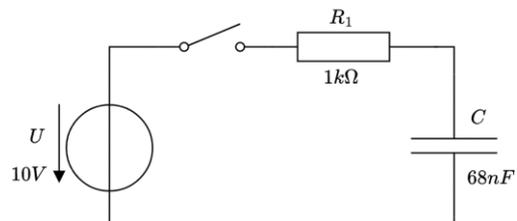
PROBLEMS

16.1 Calculate the time constant of the system (τ)! Calculate the voltage of the capacitor at the following time instances.: 0.4τ ; 0.8τ ; 1.2τ ; 2τ ; 4τ ; 5τ !

Plot the obtained results on a graph! ($\tau=68\mu\text{s}$)

16.2 Calculate the instantaneous current at the moment of switching on!

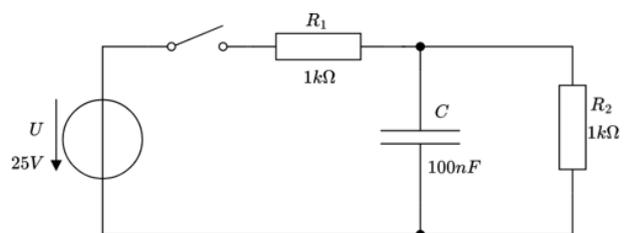
The time constant of the system is $\tau = 5\text{ms}$ ($500\mu\text{A}$)



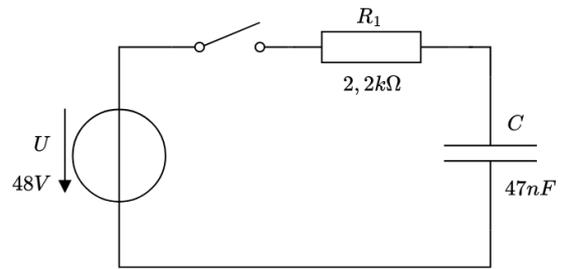
16.3 Calculate the time constant (τ) of the system based on the given values! ($\tau=50\mu\text{s}$)

Calculate the voltage of the capacitor at the following time instances.

Calculate the voltage of the capacitor at the following time instances: 0.4τ ; 0.8τ ; 1.2τ ; 2τ ; 4τ ; 5τ !



Calculate the voltage value in the steady-state condition! ($U=12.5V$)



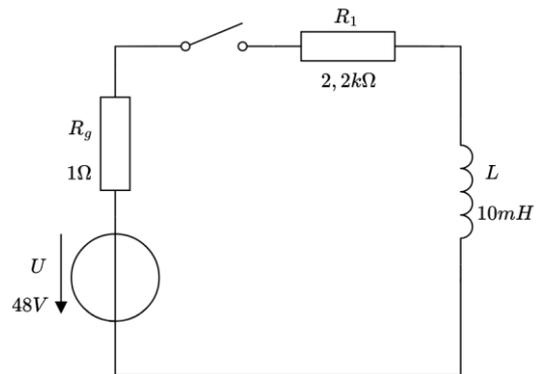
16.4 Determine the charging current and the voltage across the capacitor $70 \mu s$ after switching on! ($U=23.6V$; $I=11.09mA$)

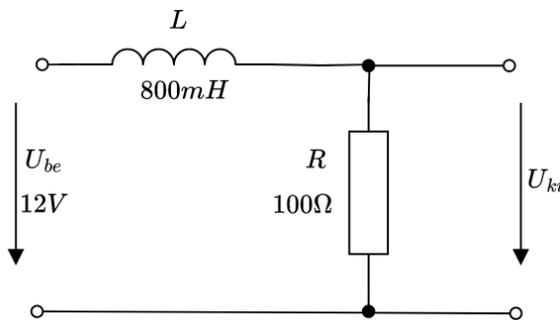
16.5 Calculate the system's time constant (τ) based on the given values! ($\tau=4.543\mu s$)

Calculate the current in the steady-state condition! ($I=21.8mA$)

Calculate the current $3 \mu s$ after switching on! ($I=10.54mA$)

What will be the voltage across the inductor $3 \mu s$ after switching on? ($U_L=24.789V$)



17. AC CIRCUITS**EXAMPLE:**

The circuit is powered with a 1.5 kHz alternating signal.

- Determine the inductive reactance (X_L) and the current (I) of the circuit! ($X_L=7,539k\Omega$; $I=1,591mA$)
- Determine the voltage across the inductor and the resistor. (U_L, U_R)! ($U_L=11,98V$; $U_R=0,159V$)
- Determine the phase angle between the supply voltage (U) and the current (I). ($\varphi=89,23^\circ$)
- Draw the phasor diagram of the circuit!
- How does the circuit behave as the frequency increases? Justify your answer!

$$X_L = 2\pi fL = 2 \cdot \pi \cdot 1500Hz \cdot 800mH = 7539.83\Omega$$

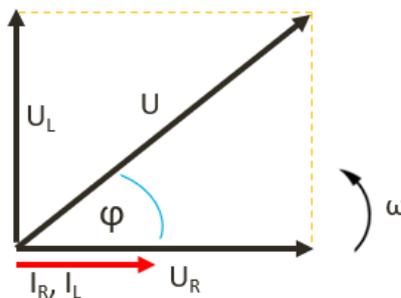
$$Z = \sqrt{100^2\Omega + 7539.83^2\Omega} = 7540.49\Omega$$

$$I = \frac{U}{Z} = \frac{12V}{7540.49\Omega} = 1.59mA$$

$$U_L = I \cdot X_L = 1.59mA \cdot 7539.83\Omega = 11.98V$$

$$U_R = I \cdot R = 1.59mA \cdot 100\Omega = 0.159V$$

$$\varphi = \operatorname{tg}^{-1}\left(\frac{U_L}{U_R}\right) = \operatorname{tg}^{-1}\left(\frac{11.98V}{0.159V}\right) = 89.23^\circ$$

**FELADATOK:**

17.1 A 1 kHz-es sinusoidal signal is given. Calculate its period! Explain in your own words what this means.

17.2 Complete the table! The table contains the instantaneous values of a sinusoidal signal. Plot the obtained values.

t (μs)	0	50	100	150	200
u (t)					

17.3 Calculate the values of a 5 kHz sinusoidal signal at the following time instances: 20 μ s, 70 μ s, 120 μ s, and 175 μ s!

17.4 The circuit is powered with a 2.5 kHz alternating signal. Calculate:

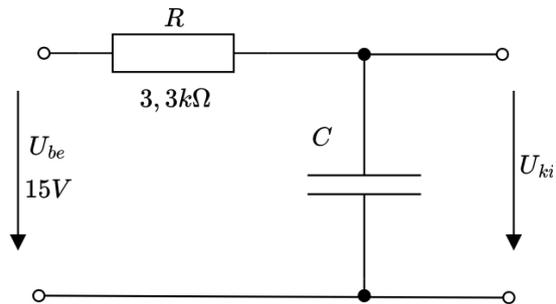
a. Calculate the capacitance of the capacitor if the cutoff frequency is known $f_h = 3.2$ kHz! ($C=15$ nF)

b. The input impedance and current! ($Z=5.37$ k Ω ; $I_{in}=2.79$ mA)

c. The magnitude of the output voltage, as well as the phase angle between the supply voltage (U) and the current (I). ($U_{out}=11.84$ V; $\varphi \cong 52^\circ$)

d. Draw the phasor diagram of the circuit!

e. How does the circuit behave as the frequency increases? Justify your answer!



17.5 The cutoff frequency of the circuit is $f_h = 7$ kHz.

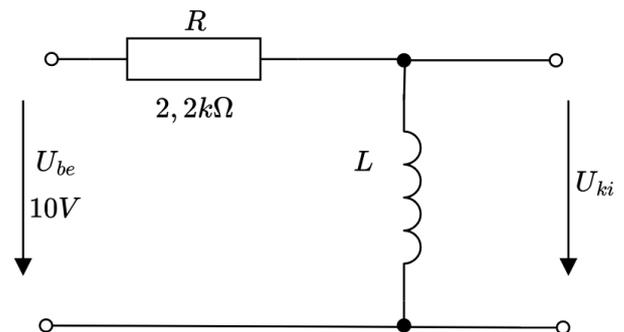
a. Calculate the inductance (L) of the coil! ($L=50$ mH)

b. The input impedance (Z) and current (I)! ($Z=3.11$ k Ω ; $I_{in}=3.125$ mA)

c. The magnitude of the output voltage and the attenuation in decibels! ($U_{out} = 7.07$ V; $A_u = -3$ dB)

d. A 150 mH inductor (L) is connected in parallel to the output. Determine the new cutoff frequency! ($f=9.337$ kHz)

e. Draw the phasor diagram of the circuit!

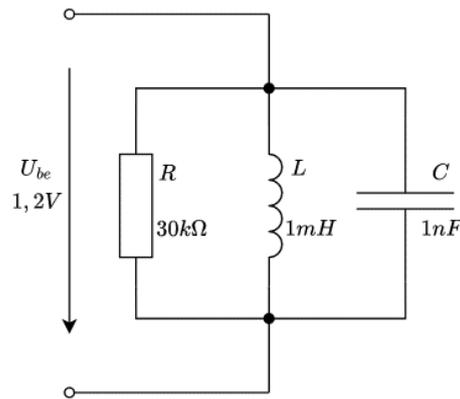


17.6 a. Calculate the value of the resonance frequency! (159.154kHz)

b. Determine the inductive reactance (X_L) and the capacitive reactance (X_C) at the resonance frequency! ($X_L=1k\Omega$; $X_C=1k\Omega$)

c. Determine the current through each component as well as the current in the main branch! (I_C , I_R , I_L , I)! ($I_R=I=40\mu A$)

d. Draw the phasor diagram of the circuit!



17.7 The circuit is powered with a 1.5 kHz alternating signal.

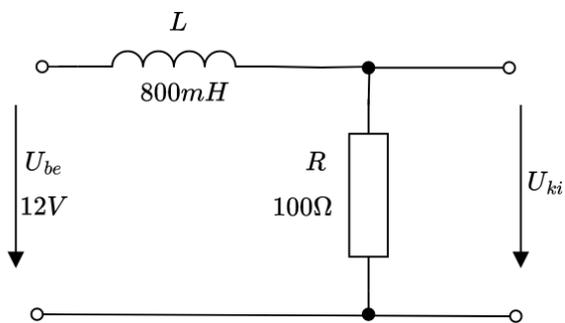
a. Determine the inductive reactance (X_L) and the current (I) of the circuit! ($X_L=7.539k\Omega$; $I=1.591mA$)

b. Determine the voltage across the inductor and the resistor (U_L , U_R)! ($U_L=11.98V$; $U_R=0.159V$)

c. Determine the phase angle between the supply voltage (U) and the current (I)! ($\varphi=89.23^\circ$)

d. Draw the phasor diagram of the circuit!

e. How does the circuit behave as the frequency increases? Justify your answer!



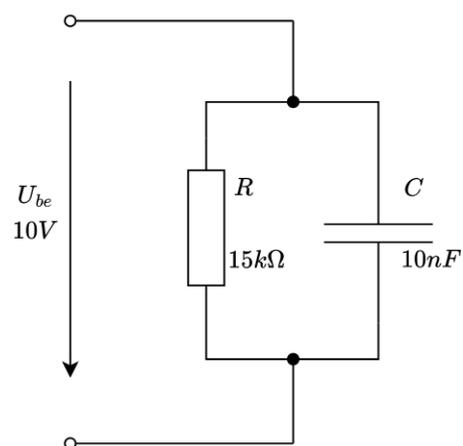
17.8 The circuit is powered with a 1.5 kHz alternating signal.

a. Calculate the capacitive reactance (X_C) of the capacitor and the impedance (Z) of the circuit. ($X_C=10.6k\Omega$; $Z=8.662k\Omega$)

b. Calculate the value of I_C , I_R , and I ! ($I_C=0.94mA$; $I_R=0.67mA$; $I=1.15mA$)

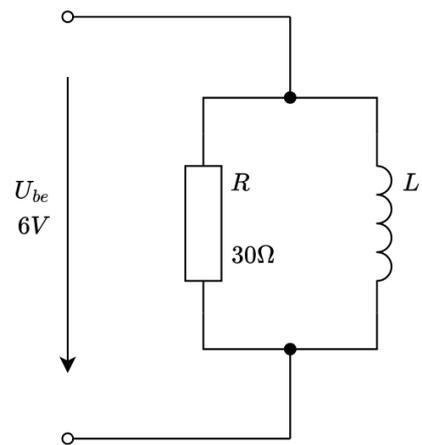
c. Determine the phase angle between the supply voltage (U) and the current (I)! ($\varphi=54.52^\circ$)

d. Draw the phasor diagram of the circuit!



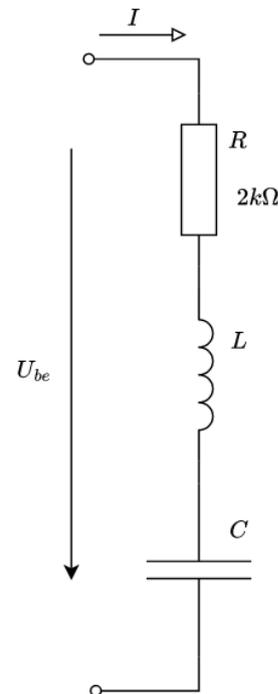
17.9 The circuit is powered with a 50 Hz alternating signal. The inductor has an inductive reactance of ($X_L = 40\Omega$).

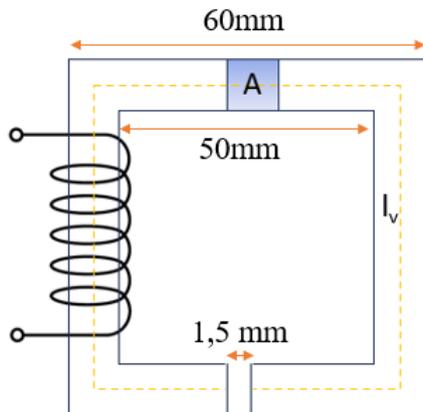
- Determine the value of the inductance (L)!
($L=0.127H$)
- Determine the currents through each component (I_L , I_R), as well as the current (I) in the main branch.
($I_L=0.15A$; $I_R=0.2A$; $I=0.25A$)
- Calculate the impedance (Z) of the circuit and the phase angle between the supply current and voltage. ($Z=24\Omega$; $\varphi=36.86^\circ$)
- Draw the phasor diagram of the circuit!



17.10 The circuit is powered with a 1 kHz signal. The inductive and capacitive reactances are given: $X_L = 2.5 k\Omega$, $X_C = 4 k\Omega$, and the supply current is $I = 4 mA$.

- Determine the voltages across the circuit elements (U_R , U_C , U_L)! ($U_R=8V$; $U_C=16V$; $U_L=10V$)
- Determine the circuit's impedance and the supply voltage. (Z , U)! ($Z=2.5k\Omega$; $U=10V$)
- Determine the values of the capacitance and the inductance (C , L)! ($C=40nF$; $L=400mH$)



18. ELECTROMAGNETIC FIELD**MINTAPÉLDA:**

A magnetic circuit is given as shown. The number of turns of the coil is 500. The relative permeability of the iron is $\mu_r = 800$. The cross-sectional area is constant throughout, $A = 2.5 \text{ cm}^2$. The excitation current is 1 A. The magnetic field strength in the iron is $H_v = 400 \text{ A/m}$.

Calculate the magnetic field strength (H), magnetic flux density (B), and magnetic flux (Φ) in the air gap.

$$l_v = 4 \cdot 55\text{mm} - 1,5\text{mm} = 0.2185\text{m}$$

$$N \cdot i = H_v \cdot l_v + H_l \cdot l_l \rightarrow H_l = \frac{N \cdot i - H_v \cdot l_v}{l_l} = \frac{500 \cdot 1\text{A} - \frac{400\text{A}}{\text{m}} \cdot 0.2185\text{m}}{0.0015\text{m}}$$

$$= 275066.67\text{A/m}$$

$$B = \mu_0 \cdot \mu_r \cdot H + \mu_0 H_l = 4\pi 10^{-7} \cdot 800 \cdot 400\text{A/m} + 4\pi 10^{-7} \cdot 275066,67\text{A/m} = 0.747\text{T}$$

$$\Phi = B \cdot A = 0.747\text{T} \cdot 2.5\text{cm}^2 = 1.86 \cdot 10^{-4}\text{Vs}$$

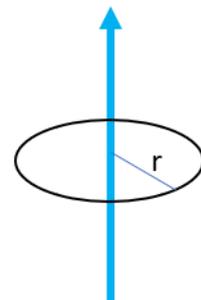
FELADATOK:

18.1 A current of 100A flows in a conductor.

Calculate the magnetic field strength at a distance r from the conductor.

The values of r are: 10cm, 20cm, 1m, and 1.5m.

What do you observe as you move farther away from the conductor?



18. In a 1mH inductor, the current decreases from 150mA to 0A in 64 μ s.

What voltage is induced in the inductor? ($U = -2.343\text{V}$)

18.3 An air-core coil with $N = 200$ turns and a length of $l = 6\text{cm}$ is supplied with a current of $I = 500\text{mA}$.

a. What is the magnitude of the magnetic flux density (B) generated inside the coil? ($B = 2.094\text{mT}$)

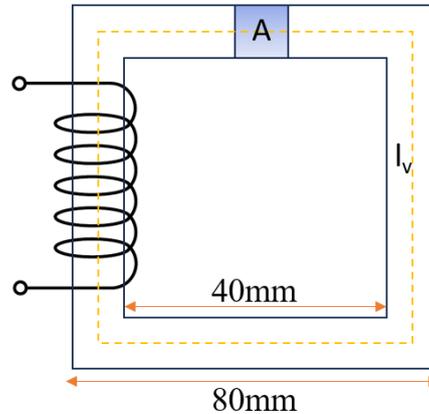
b. What is the magnitude of the magnetic flux density if, instead of air, an iron core with relative permeability $\mu_r = 300$ is used? ($B = 0.628\text{T}$)

18.4 Calculate the magnetic field strength inside a coil if the magnetic flux density is $B = 1.2\text{T}$ and the relative permeability of the iron core is $\mu_r = 1100$. ($H=868.11\text{A/m}$)

18.5 The following magnetic circuit is given. The number of turns of the coil is 250. The maximum magnetic flux density of the iron core is $B_{\max} = 0.2\text{T}$, and the relative permeability of the iron is $\mu_r = 2000$. The cross-sectional area is constant throughout, $A = 4\text{cm}^2$.

a. Calculate the excitation current required if the coil has an air core! ($i=152.78\text{A}$)

b. Calculate the excitation current required if an iron core with the above-given parameters is used! ($i=0.07639\text{A} = 76.39\text{mA}$)



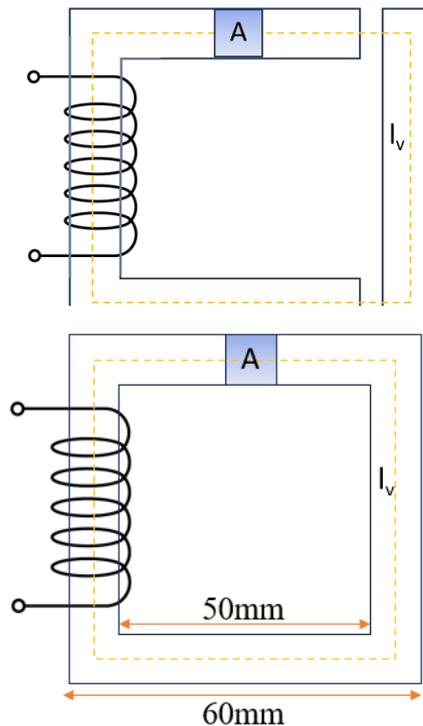
18.6 The geometry of the magnetic circuit corresponds to problem 18.5. Calculate the excitation current required for a 500-turn winding so that the magnetic flux density is 0.5T ($\mu_r = 105$). The cross-sectional area is constant at 5cm^2 . ($i = 1.909\text{mA}$)

18. The following magnetic circuit is given. The coil has 500 turns. The average length of the magnetic path in the iron is $l_v = 360\text{mm}$. There is a single air gap of length $l_l = 1.5\text{mm}$. The excitation current is 0.5A . The magnetic field strength in the iron is 510A/m .

a. What is the magnetic field strength in the air gap? ($H=22133.3\text{A/m}$)

b. Calculate the relative permeability of the iron core if the magnetic flux density is 0.8T ! ($\mu_r=1204.8$)

c. If the magnetic circuit contains no air gap (0mm), what current is required to excite the coil so that the magnetic flux density in the iron is $B = 0.8\text{T}$ (μ_r as in the previous task)? ($i=0.38\text{A}$)

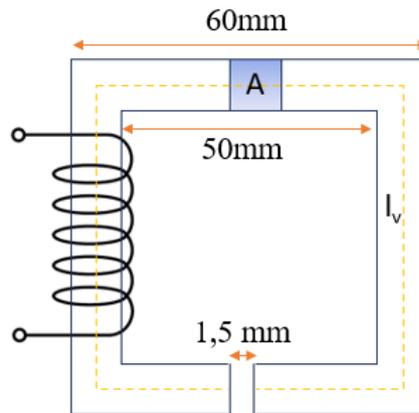


18.8 The following magnetic circuit is given. The coil has 500 turns. The relative permeability of the iron is $\mu_r = 800$. The cross-sectional area is constant throughout, $A = 2.5\text{cm}^2$. The excitation current is 1A .

Calculate the magnetic field strength (H), magnetic flux density (B), and flux (Φ) in the iron core! ($H=2272.72\text{A/m}$; $B=2.28\text{T}$; $\Phi=5.72\text{e}^{-4}\text{Vs}$)

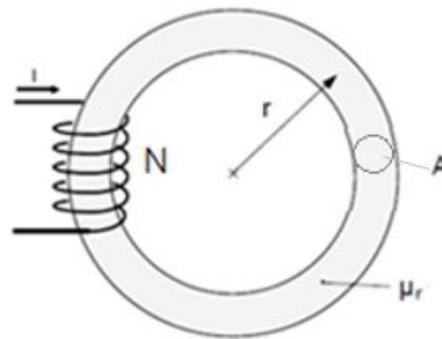
18.9 The parameters of the magnetic circuit correspond to problem 18.8, except that a 1.5mm air gap has been inserted into the iron core, and the magnetic field strength in the iron is given as 400A/m.

Calculate the magnetic field strength (H), magnetic flux density (B), and flux (Φ) in the air gap! ($H=275066.67\text{A/m}$; $B=0.747\text{T}$; $\Phi=1.86\text{e}^{-4}\text{Vs}$)



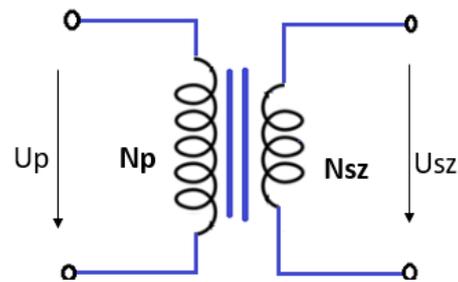
18.10 The parameters of the magnetic circuit are as follows: $r = 40\text{cm}$; $N = 900$; $i = 4000\text{mA}$; $\mu_r = 400$; $A = 20\text{cm}^2$.

- Calculate the magnetic field strength (H) in the powder core! ($H=1434.26\text{A/m}$)
- What is the magnetic flux density (B) in the powder core? ($B=0.72\text{T}$)
- Calculate the value of the flux (Φ)! ($\Phi=1.44\text{e}^{-3}\text{Vs}$)



18.11 The parameters of the following transformer are as follows: $U_p = 230\text{V}$; $N_p = 1200$; $N_s = 300$.

- Calculate the voltage across the secondary winding! ($U=57.5\text{V}$)
- A resistor of $R = 100\ \Omega$ is connected to the secondary winding. What current will flow in the primary (I_p) and secondary (I_s) windings? ($I_{sz}=0.575\text{A}$; $I_p=0.14375\text{A}$)



18.12 Complete the following table. The table contains data related to a transformer!

N_p	U_p [V]	I_p [A]	P_p [W]	N_{sz}	U_{sz} [V]	I_{sz} [A]	P_{sz} [W]
600	200			300			1000
1200	200			600			1000
	50			1200		10	2000

19. BASICS OF SEMICONDUCTORS**EXAMPLE:**

Calculate the emitter current (I_E) and the collector current (I_C) of an NPN bipolar transistor if the base current is $I_B = 25 \mu\text{A}$ and the transistor current gain is $\beta = 250$. The transistor operates in the active region. ($I_C = 6.25\text{mA}$; $I_E = 6.275\text{mA}$)

$$I_C \cdot I_E = ?$$

$$I_C = \beta \cdot I_B = 250 \cdot 25 \mu\text{A} = 6.25\text{mA}$$

$$I_E = (1 + \beta) \cdot I_B = (1 + 250) \cdot 25 \mu\text{A} = 6.275\text{mA}$$

PROBLEMS:

19.1 Size the series resistor for the LED.

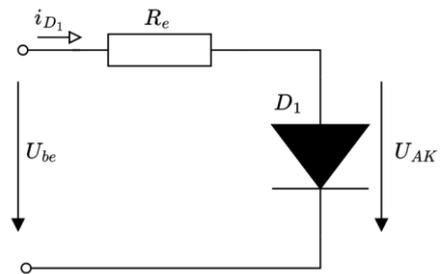
Parameters:

$$U_{be} = 5\text{V}$$

$$I_{D1} = 20\text{mA}$$

$$U_{AK} = 2\text{V}$$

Calculate the resistor value for $U_{be} = 10\text{V}$, 12V , 20V , and 24V as well. ($R_{5\text{V}} = 150\Omega$; $R_{10\text{V}} = 400\Omega$; $R_{12\text{V}} = 500\Omega$; $R_{20\text{V}} = 900\Omega$; $R_{24\text{V}} = 1.1\text{k}\Omega$)



19.2 Calculate the emitter current (I_E) and the collector current (I_C) of an NPN bipolar transistor if the base current is $I_B = 25 \mu\text{A}$ and the transistor current gain is $\beta = 250$. The transistor operates in the active region. ($I_C = 6.25\text{mA}$; $I_E = 6.275\text{mA}$)