Exam Preparation: Electric Current

Theory: Answer the questions and explain the concepts by heart

a) Vector/scalar
b) Give examples of scalars
c) Give examples of vectors
d) Explain the meaning of "inertia" as a property of mass.
e) Explain the meaning of "gravity" as a property of mass.
f) Definition of work
g) Elementary charge
h) Electric Field
i) Uniform field
j) Voltage
k) Electric current
l) What is the purpose of electric current?
m) Direct current
n) Alternating current
o) Ammeter / how is it connected in a circuit?
p) Voltmeter / how is it connected in a circuit?
q) Electrical resistance
r) What does the electrical resistance of a wire depend on? Give four options.
s) Energy
t) Power
u) Efficiency
v) What is a short circuit? What happens to the current if a short circuit occurs?

Physical quantities: Know these physical quantities by heart (symbol and unit)

	symbol	unit		symbol	unit
time			displacement		
velocity			acceleration		
force			mass		
radius, distance			length		
work			power		
energy			internal energy		
efficiency			charge		
electric current			resistance		
electric field strength			voltage		

Formulae: A formula sheet will be handed out. Please find the formula sheet on massenpunkt.ch.

Skills:

- Transform equations, insert numbers with units into the equation, calculate results correctly
- Round your results to the correct number of significant digits and write your answer with a power of ten in the normalized scientific format
- Draw and read scientific graphs
- draw and read electric field line patterns
- draw and read magnetic field line patterns
- Convert the unit *Pascal* to *bar* and vice versa
- Convert the unit *kWh* to *J* and vice versa
- Convert the unit *eV* to *J* and vice versa
- Convert units for area and volume
- draw and read electric circuit diagrams

Exercises:

An algebraic solution and all values used in calculations are required to get the full mark.

All work sheets plus assignment sheets A51 – A53

Additional problems

1. A little light bulb consumes a power of 0.254900 W when a voltage of 0.00850 kV is applied across it. The electric current passing through the filament of the light bulb is to be calculated.
a) Place a dot above the significant figures of the values which are required in the calculation. How many significant digits do they have? How many significant figures does your final answer require?
b) Calculate the current passing through the filament of the light bulb.
c) Round your result to the correct number of significant figures and write it in the normalized scientific notation (with a power of ten).

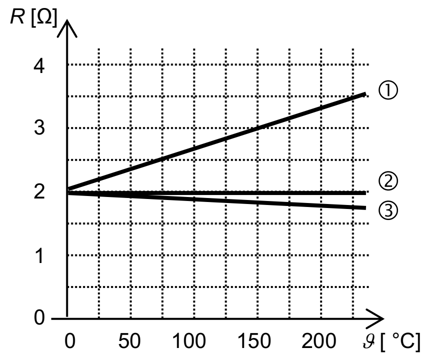
2. Complete the following sentences:
a) An ammeter is connected in ………………………….. (*series* / *parallel*). Its resistance is very ………………………….. (*large* / *small*), and ……………………………..………….. (*hardly any electric current passes* / *the electric current passes virtually unhindered*) through the meter.
b) A voltmeter is connected in ………………………….. (*series* / *parallel*). Its resistance is very ………………………….. (*large* / *small*), and ………………………..……………….. (*hardly any electric current passes* / *the electric current passes virtually unhindered*) through the meter.

3. Calculate the missing quantities. Please write down the formula you used for your calculation, solved for the wanted quantity.

voltage	current	resistance	charge	time	power	work	cost
			2'500 C	1.0 h		4.6 kJ	
220 V					245 W	700 kJ	
	490 mA			45 min		0.07 kWh	
380 V					7.9 kW		6.0 Rp.

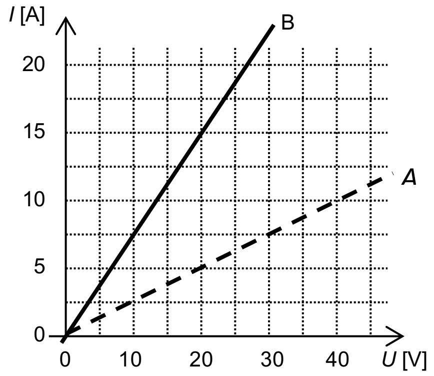
4. A current of 0.300 A passes through a light bulb when a voltage of 230.0 V is applied across it.
a) Calculate the resistance of the light bulb.
b) How much charge passes through a cross section of the light bulb's filament in one minute?
c) How long does it take for 100'000 electrons to pass through a cross sectional area of the light bulb's filament?

5. Here's a graph showing how the electrical resistance of three wires made of three different materials ①, ② and ③ relates to temperature.
a) Describe in your own words how the electrical resistance of three different materials ①, ② and ③ changes, while the temperature increases.
b) What materials could ①, ② and ③ be?



6. A resistor of 1.057 kΩ is connected to a voltage source of 3.4 mV. How many electrons are passing through the resistor in $7.0 \cdot 10^{-7}$ s?

7. The graph shows how electric current depends on the voltage applied across two wires of constant resistance A and B.



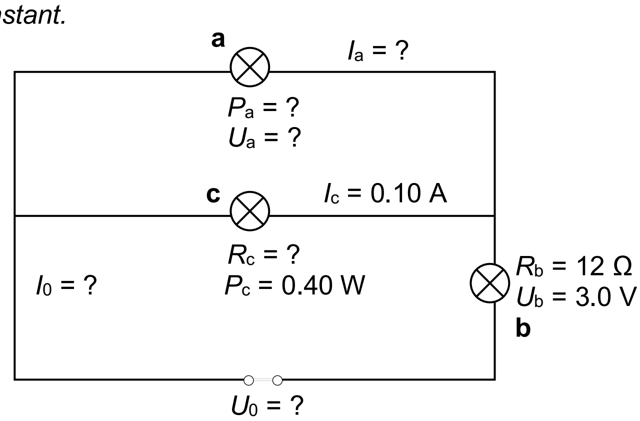
a) Which ones of the wires has a greater resistance: A or B?
b) Determine the current in wire A at a voltage of 30.0 V.
c) Draw the graph of wire C, which has a constant resistance of R = 0.50 Ω.
d) Draw the graph of wire D, which does not have a constant resistance. The resistance of wire D doubles as voltage is quadrupled. (Several correct answers are possible.)

8. Mick came back from the United States where he bought an immersion heater. If connected to 110.0 V, it operates correctly and consumes 530.0 W. Back home in Europe Mick plugs the immerson heater into a power outlet of 220 V. The fuse blows at a current which is greater than 10.0 A. Assuming the resistance of the immersion heater is a constant, what happens? Does the device work? If yes, what is the power consumed? If no, why not?

9. An electric heater is labelled 1.90 kW/230 V.
a) Calculate the cost of running the heater for 85 min.
b) What would the electric heater's power be at 130 V? *Assume the heater's resistance is a constant.*

10. Three light bulbs are connected in a circuit as shown in the diagram.
a) Which ones of the lamps need to be unscrewed from the socket for
   - one lamp
   - all lamps

   to go out?
b) Which ones of the lamps are connected in parallel, which ones are connected in series?
c) Determine the missing values and write them in the picture.



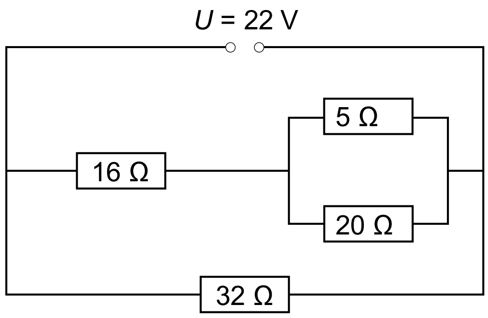
11. The efficiency of an electric motor is 70.0 %, the power supplied is 50.0 kW.
    What is the extracted power output?

12. Three resistors R_1 = 3.0 Ω, R_2 = 4.0 Ω and R_3 = 5.0 Ω are connected in parallel to a voltage source of 12.0 V.
a) What are the individual voltages across each of the three resistors?
b) What is the total voltage?
c) What are the individual currents passing through each of the resistors?
d) What is the total current?
e) What are the individual powers consumed by each of the resistors?
f) What is the total power?
g) What is the equivalent resistance?

13. Three resistors R_1 = 3.0 Ω, R_2 = 4.0 Ω and R_3 = 5.0 Ω are connected in series to a voltage source. The current passing through them is 1.0 A.
a) What are the individual voltages across each of the three resistors?
b) What is the total voltage?
c) What are the individual currents passing through each of the resistors?
d) What is the total current?
e) What are the individual powers consumed by each of the resistors?
f) What is the total power?
g) What is the equivalent resistance?

14. A solar panel converts light (radiant energy) into electrical energy. The efficiency is about 15 %. The gained electrical energy is used for powering an LED light bulb (η = 30.0 %). What is the electrical energy gained by the solar panel?
    Calulate the total efficiency of the combined devices.

15.



a) Determine the equivalent resistance.
b) What is the current passing through the 16 Ω-resistor?
c) What is the voltage applied across the 5 Ω-resistor?
d) We want the same amount of current to flow through the 16 Ω resistor as through the 32 Ω resistor. This is to be achieved by replacing the 5 Ω resistor by another resistor. Calculate the resistance of the resistor that replaces the 5 Ω resistor.

Solutions:

1. a) $U = 0.00\dot{8}\dot{5}\dot{0}$ kV: 3 significant digits; $P = 0.\dot{2}\dot{5}\dot{4}\dot{9}\dot{0}\dot{0}$ W: 6 significant digits; result: 3 digits
   b) $I = \frac{P}{U} = \frac{0.254900 \text{ W}}{8.50 \text{ V}}$ = 0.029988345 A = 0.0300 A
   c) <u>$3.00 \cdot 10^{-2}$ A</u>

2. a) series, small, the electric current passes virtually unhindered
   b) parallel, large, hardly any electric current passes

3.

1.84 V	0.69 A	2.65 Ω	1.28 W	0.03 Rp.
1.1 A	197.5 Ω	3181.8 C	47 min 37 s	3.9 Rp.
190.5 V	388.7 Ω	1323 C	93.3 W	1.4 Rp.
20.8 A	18.3 Ω	2842 C	136.7 s	0.3 kWh = 1080 kJ

4. a) $R = \frac{U}{I} = \frac{230\text{ V}}{0.300\text{ A}} = \underline{\underline{767\ \Omega}}$

b) $Q = I \cdot t = 0.300\text{ A} \cdot 60.0\text{ s} = \underline{\underline{18.0\text{ C}}}$

c) 100'000 electrons have a charge of $Q = 100'000 \cdot 1.602 \cdot 10^{-19}\text{ C} = 1.602 \cdot 10^{-14}\text{ C}$

$$t = \frac{Q}{I} = \frac{1.602 \cdot 10^{-14}\text{ C}}{0.300\text{ A}} = \underline{\underline{5.34 \cdot 10^{-14}\text{ s}}}$$

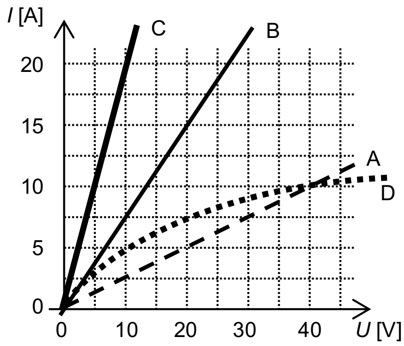
5. a) ①: The resistance increases with increasing temperature
②: The resistance does not depend on the temperature
③: The resistance decreases with increasing temperature
b) ①: metal, ②: constantan ③: carbon, semiconductor

6. $I = \frac{U}{R} = \frac{0.0034\text{ V}}{1057\ \Omega} = 0.000003217\text{ A} = 3.22 \cdot 10^{-6}\text{ A}$

$Q = I \cdot t = 3.22 \cdot 10^{-6}\text{ A} \cdot 7.0 \cdot 10^{-7}\text{ s} = 2.25 \cdot 10^{-12}\text{ C}$

This is $N = \frac{2.25 \cdot 10^{-12}\text{ C}}{1.602 \cdot 10^{-19}\ \frac{\text{C}}{\text{electron}}} = \underline{\underline{14'072'848\text{ electrons}}} = \underline{\underline{1.4 \cdot 10^{7}\text{ electrons}}}$

7. a) A
b) 7.5 A
c) straight line through 10 A/5 V, 20 A/10 V, etc.
d) e. g. curved graph through 5 A/10V (2 Ω) and 10 A/40 V (4 Ω)



8. $I = \frac{P}{U} = \frac{530\text{ W}}{110\text{ V}} = 4.81\text{ A}$ ⇒ $R = \frac{U}{I} = \frac{110\text{ V}}{4.81\text{ A}} = 22.8\ \Omega$ $I = \frac{U}{R} = \frac{220\text{ V}}{22.8\ \Omega} = 9.6\text{ A}$

⇒ yes, it works ⇒ $P = U \cdot I = \underline{\underline{2'120\text{ W}}}$

9. a) $W = P \cdot t = 1.90\text{ kW} \cdot \frac{85}{60}\text{ h} = 2.69\text{ kWh}$ costs $2.69\text{ kWh} \cdot 20\ \frac{\text{Rp.}}{\text{kWh}} = \underline{\underline{53.8\text{ Rp.}}}$

b) $R = \frac{U^2}{P} = \frac{(230\text{ V})^2}{1'900\text{ W}} = 27.84\ \Omega$ $I = \frac{U}{R} = \frac{130\text{ V}}{27.84\ \Omega} = 4.669\text{ A}$

$P = U \cdot I = 130\text{ V} \cdot 4.669\text{ A} = \underline{\underline{607\text{ W}}}$

10. a) a or c; b
b) a and c in parallel, in series to b

c) $I_0 = I_b = \frac{U_b}{R_b} = \frac{3.0\text{ V}}{12\ \Omega} = \underline{\underline{0.25\text{ A}}}$ $I_a = I_0 - I_c = 0.25\text{ A} - 0.10\text{ A} = \underline{\underline{0.15\text{ A}}}$

$U_a = U_c = \frac{P_c}{I_c} = \frac{0.40\text{ W}}{0.10\text{ A}} = \underline{\underline{4.0\text{ V}}}$ $P_a = U_a \cdot I_a = 4.0\text{ V} \cdot 0.15\text{ A} = \underline{\underline{0.60\text{ W}}}$

$R_c = \frac{U_c}{I_c} = \frac{4.0\text{ V}}{0.10\text{ A}} = \underline{\underline{40\ \Omega}}$ $U_0 = U_a + U_b = 4.0\text{ V} + 3.0\text{ V} = \underline{\underline{7.0\text{ V}}}$

11. $P_{useful} = P_{consumed} \cdot \eta = 50.0\text{ kW} \cdot 0.700 = \underline{\underline{35.0\text{ kW}}}$

12. a) $U_1 = U_2 = U_3 = 12$ V
    b) $U_{total} = 12$ V
    c) $I_1 = \frac{U}{R_1} = \frac{12\text{ V}}{3.0\ \Omega} = 4.0\text{ A}$, $I_2 = \frac{U}{R_2} = \frac{12\text{ V}}{4.0\ \Omega} = 3.0\text{ A}$, $I_3 = \frac{U}{R_3} = \frac{12\text{ V}}{5.0\ \Omega} = 2.4\text{ A}$
    d) $I_{total} = I_1 + I_2 + I_3 = 4.0\text{ A} + 3.0\text{ A} + 2.4\text{ A} = 9.4\text{ A}$
    e) $P_1 = U_1 \cdot I_1 = 12\text{ V} \cdot 4.0\text{ A} = 48\text{ W}$, $P_2 = U_2 \cdot I_2 = 12\text{ V} \cdot 3.0\text{ A} = 36\text{ W}$,
    $P_3 = U_3 \cdot I_3 = 12\text{ V} \cdot 2.4\text{ A} = 28.8\text{ W}$
    f) $P_{total} = U_{total} \cdot I_{total} = 12\text{ V} \cdot 9.4\text{ A} = 112.8\text{ W}$,
    or $P_{total} = P_1 + P_2 + P_3 = 48\text{ W} + 36\text{ W} + 28.8\text{ W} = 112.8\text{ W}$
    g) $R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{3.0\ \Omega} + \frac{1}{4.0\ \Omega} + \frac{1}{5.0\ \Omega}} = \underline{\underline{1.3\ \Omega}}$
    or $R_{total} = \frac{U_{total}}{I_{total}} = \frac{12\text{ V}}{9.4\text{ A}} = \underline{\underline{1.3\ \Omega}}$

13. a) $U_1 = R_1 \cdot I = 3.0\ \Omega \cdot 1.0\text{ A} = 3.0\text{ V}$, $U_2 = R_2 \cdot I = 4.0\ \Omega \cdot 1.0\text{ A} = 4.0\text{ V}$,
    $U_3 = R_3 \cdot I = 5.0\ \Omega \cdot 1.0\text{ A} = 5.0\text{ V}$
    b) $U_{total} = U_1 + U_2 + U_3 = 3.0\text{ V} + 4.0\text{ V} + 5.0\text{ V} = 12\text{ V}$
    c) $I_1 = I_2 = I_3 = 1.0$ A
    d) $I_{total} = 1.0$ A
    e) $P_1 = U_1 \cdot I_1 = 3.0\text{ V} \cdot 1.0\text{ A} = 3.0\text{ W}$, $P_2 = U_2 \cdot I_2 = 4.0\text{ V} \cdot 1.0\text{ A} = 4.0\text{ W}$,
    $P_3 = U_3 \cdot I_3 = 5.0\text{ V} \cdot 1.0\text{ A} = 5.0\text{ W}$
    f) $P_{total} = U_{total} \cdot I_{total} = 12\text{ V} \cdot 1.0\text{ A} = 12.0\text{ W}$,
    or $P_{total} = P_1 + P_2 + P_3 = 3.0\text{ W} + 4.0\text{ W} + 5.0\text{ W} = 12.0\text{ W}$
    g) $R_{eq} = R_1 + R_2 + R_3 = 3.0\ \Omega + 4.0\ \Omega + 5.0\ \Omega = 12.0\ \Omega$
    or $R_{total} = \frac{U_{total}}{I_{total}} = \frac{12\text{ V}}{1.0\text{ A}} = \underline{\underline{12.0\ \Omega}}$

14. $\eta_{total} = \eta_1 \cdot \eta_2 = 0.15 \cdot 0.300 = 0.045 = \underline{\underline{4.5\ \%}}$

15. a) $R_{(5\ \Omega,\ 20\ \Omega)} = \frac{R_{5\ \Omega} \cdot R_{20\ \Omega}}{R_{5\ \Omega} + R_{20\ \Omega}} = \frac{5\ \Omega \cdot 20\ \Omega}{25\ \Omega} = 4\ \Omega$
    $R_{(5\ \Omega,\ 20\ \Omega,\ 16\ \Omega)} = R_{(5\ \Omega,\ 20\ \Omega)} + R_{(16\ \Omega)} = 4\ \Omega + 16\ \Omega = 20\ \Omega$
    $R_{(5\ \Omega,\ 20\ \Omega,\ 16\ \Omega,\ 32\ \Omega)} = = \frac{R_{32\ \Omega} \cdot R_{5\ \Omega,\ 20\ \Omega,\ 16\ \Omega}}{R_{32\ \Omega} + R_{5\ \Omega,\ 20\ \Omega,\ 16\ \Omega}} = \frac{32\ \Omega \cdot 20\ \Omega}{52\ \Omega} = \underline{\underline{12.3\ \Omega}}$
    b) $I_{middle\ branch} = \frac{U_{total}}{R_{eq\ (middle\ branch)}} = \frac{U_{total}}{R_{5\ \Omega,\ 20\ \Omega,\ 16\ \Omega}} = \frac{22\text{ V}}{20\ \Omega} = \underline{\underline{1.1\text{ A}}}$
    c) $U_{5\ \Omega} = U_{20\ \Omega} = R_{eq(5\ \Omega,\ 20\ \Omega)} \cdot I_{middle\ branch} = 4\ \Omega \cdot 1.1\text{ A} = \underline{\underline{4.4\text{ V}}}$
    d) For $I_{middle\ branch} = I_{lower\ branch}$ to be fulfilled, we need $R_{(unknown,\ 20\ \Omega,\ 16\ \Omega)} = R_{(32\ \Omega)} = 32\ \Omega$
    Therefore, $R_{eq(unknown,\ 20\ \Omega)} = R_{(unknown,\ 20\ \Omega,\ 16\ \Omega)} - R_{16\ \Omega} = 32\ \Omega - 16\ \Omega = 16\ \Omega$
    $\frac{1}{R_{eq(unknown,\ 20\ \Omega)}} = \frac{1}{R_{unknown}} + \frac{1}{R_{20\ \Omega}}$ $\qquad \frac{1}{R_{unknown}} = \frac{1}{R_{eq(unknown,\ 20\ \Omega)}} - \frac{1}{R_{20\ \Omega}}$
    $R_{(unknown)} = \frac{R_{20\ \Omega} \cdot R_{eq(unknown,\ 20\ \Omega)}}{R_{20\ \Omega} - R_{eq(unknown,\ 20\ \Omega)}} = \frac{20\ \Omega \cdot 16\ \Omega}{20\ \Omega - 16\ \Omega} = \underline{\underline{80\ \Omega}}$