

EXAM PREPARATION: ELECTROMAGNETIC INDUCTION, RELATIVITY, RADIOACTIVITY

Theory: Answer the questions and explain the concepts by heart

- a) Explain the meaning of "inertia" as a property of mass.
- b) Explain the meaning of "gravity" as a property of mass.
- c) Voltage
- d) Electric current
- e) What is the purpose of electric current?
- f) Definition of work
- g) Power
- h) Energy
- i) Elementary charge
- j) Magnetic field
- k) Electric field
- l) Uniform field
- m) Explain Lenz' law
- n) Definition of the effective values of an alternating voltage and current
- o) Magnetic flux
- p) Give two conditions when an induced voltage between the ends of a loop of wire in a magnetic field can be measured
- q) Reference frame
- r) Inertial reference frame
- s) Einstein's postulates (two)
- t) What follows from Einsteins postulates for the physical quantities "time" and "length" for an object moving at a velocity close to the speed of light?
- u) Describe a radioactive decay using an example
- v) Half life
- w) Decay constant
- x) Activity

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 units for area and volume
- Convert angles from degree to radian
- Draw and read electric circuit diagrams
- Make proper use of the "left-hand rule"
- Make proper use of the "three-finger rule"
- Explain how an electric motor works
- Explain how a generator works

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			speed of light		
charge			electric current		
voltage			resistance		
magnetic field			magnetic flux		
peak voltage			frequency		
period			angular velocity		
half-life			decay constant		
activity					

Exercises:

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

All work sheets plus assignment sheets A59 – A62

Additional problems

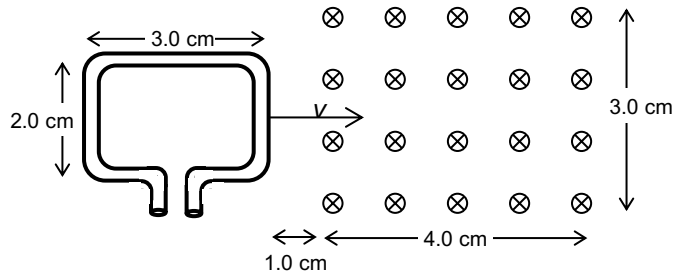
- Morris ($m = 65.0 \text{ kg}$) and Maurice ($m = 65.0 \text{ kg}$) are travelling in their super fast space ships, with a velocity of $150'000 \frac{\text{km}}{\text{s}}$ relative to each other. They both have identical, very accurate watches. They also have identical, very accurate rulers.
Complete the following sentences using (*faster/slower/shorter/longer*):

 - Morris says: "Maurice's watch is running than mine."
 - Maurice says: "Morris' watch is running than mine."
 - Morris says: "Maurice's ruler is than mine."
 - Maurice says: "Morris' ruler is than mine."
- What is the speed of a Porsche, if a person standing at the side of the road perceives its length to be half of the length of what it is from the driver's perspective (no friction, no air resistance)?

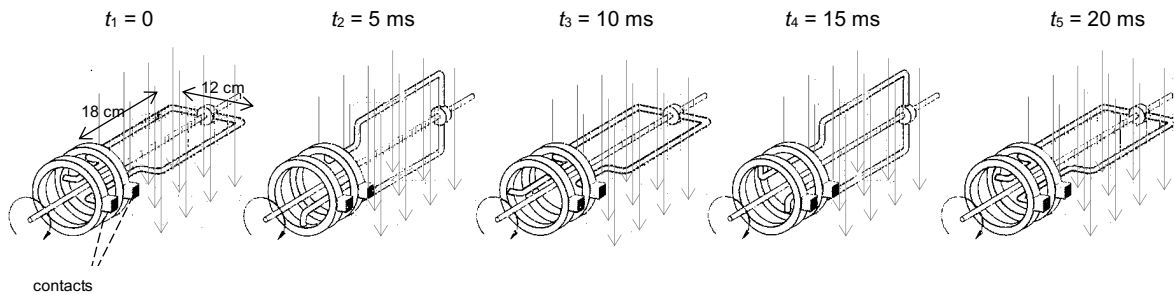
3. A square loop of wire is located in a magnetic field ($B = 0.0150 \text{ T}$), perpendicular to the field lines. The magnetic flux is 0.0149940 Wb . The length of one of the sides of the loop of wire is to be calculated (in mm).
 - a) Place a dot above the significant figures of the values which are required in the calculation. How many significant digits do they have? How many significant figures does your final answer require?
 - b) Calculate the length of one of the sides of the loop of wire (in mm).
 - c) Round your result to the correct number of significant figures and write it in the normalized scientific notation (with a power of ten).

4. A rectangular loop of wire is moving at a speed of $1.0 \frac{\text{cm}}{\text{s}}$ in and out of a uniform magnetic field ($B = 2.50 \text{ mT}$).

- a) When is a magnetic flux through the loop of wire present, when does it increase, when does it decrease?
- b) When is a voltage induced? What is the magnitude of the induced voltage?



5. Here are five pictures of a loop of wire that is rotated in a magnetic field ($B = 0.45 \text{ T}$)



- a) Draw in the picture the direction of motion of the two parts of the loop of wire.
- b) Draw in the picture the direction of motion of the electrons in the loop of wire (in some of the pictures the electrons do not move).
- c) Which one of the contacts is a plus, which one is a minus pole? Draw it in the pictures.
- d) In some of the pictures a magnetic force acts on the moving electrons in the loop of wire. In the cases, where a magnetic force is acting, draw the direction of this force.
- e) How long does a whole revolution of the loop of wire take?
- f) What is the frequency?
- g) What is the angular velocity?
- h) What is the peak value of the induced voltage?
- i) What is the effective value of the induced voltage?
- j) If the contacts are connected to a lamp to close the electric circuit, it becomes harder to turn the loop of wire. Why?

6. A radioactive sample contains $6.24 \cdot 10^{16}$ Strontium-90 nuclei.

- a) Calculate the activity.
- b) How long does it take until only $2.7 \cdot 10^{15}$ nuclei are left?

7. After 223 h 39 min, the activity of a radioactive sample is 88% of its initial value. What is the half-life? What element is it?

Solutions:

1. a) slower
b) slower
c) shorter
d) shorter

2. $\frac{\ell}{\ell_0} = \frac{1}{2} \quad v = c \cdot \sqrt{1 - \left(\frac{\ell}{\ell_0}\right)^2} = 299'792'458 \frac{\text{m}}{\text{s}} \cdot \sqrt{1 - \left(\frac{1}{2}\right)^2} = \underline{\underline{2.596 \cdot 10^8 \frac{\text{m}}{\text{s}}}}$

3. a) $B = 0.0150 \text{ T}$: 3 significant figures, $\Phi = 0.0149940 \text{ Tm}^2$: 6 significant figures, result: 3 figures

b) $A = \frac{\Phi}{B} \quad s = \sqrt{\frac{\Phi}{B}} = \sqrt{\frac{0.0149940 \text{ T} \cdot \text{m}^2}{0.0150 \text{ T}}} = 0.99979998 \text{ m} = 1.00 \text{ m}$

c) $\underline{\underline{1.00 \cdot 10^3 \text{ mm}}}$

4. a) From $t = 0$ to $t = 1.0 \text{ s}$: no magnetic flux, no change in magnetic flux
from $t = 1.0 \text{ s}$ to $t = 4.0 \text{ s}$: Area increases \Rightarrow magnetic flux increases
from $t = 4.0 \text{ s}$ to $t = 5.0 \text{ s}$: Area does no change \Rightarrow no change in magnetic flux
from $t = 5.0 \text{ s}$ to $t = 8.0 \text{ s}$: Area decreases \Rightarrow magnetic flux decreases
from $t = 8.0 \text{ s}$ to $t = 10.0 \text{ s}$: no magnetic flux, no change in magnetic flux

- b) From $t = 0$ to $t = 1.0 \text{ s}$: no change in magnetic flux, $U_{\text{ind}} = \underline{\underline{0}}$

from $t = 1.0 \text{ s}$ to $t = 4.0 \text{ s}$:

Area increases by $\Delta A = 0.010 \text{ m} \cdot 0.020 \text{ m} = 2.0 \cdot 10^{-4} \text{ m}^2$ per second

$$U_{\text{ind}} = -\frac{\Delta\Phi}{\Delta t} = -\frac{\Delta A \cdot B}{\Delta t} = -\frac{2.0 \cdot 10^{-4} \text{ m}^2 \cdot 2.50 \cdot 10^{-3} \text{ T}}{1.0 \text{ s}} = \underline{\underline{-5.0 \cdot 10^{-7} \text{ V}}}$$

from $t = 4.0 \text{ s}$ to $t = 5.0 \text{ s}$: no change in magnetic flux, $U_{\text{ind}} = \underline{\underline{0}}$

from $t = 5.0 \text{ s}$ to $t = 8.0 \text{ s}$:

Area decreases by $\Delta A = 0.010 \text{ m} \cdot 0.020 \text{ m} = 2.0 \cdot 10^{-4} \text{ m}^2$ per second:

$$U_{\text{ind}} = -\frac{\Delta\Phi}{\Delta t} = -\frac{-\Delta A \cdot B}{\Delta t} = -\frac{-2.0 \cdot 10^{-4} \text{ m}^2 \cdot 2.50 \cdot 10^{-3} \text{ T}}{1.0 \text{ s}} = \underline{\underline{5.0 \cdot 10^{-7} \text{ Tm}^2}}$$

from $t = 8.0 \text{ s}$ to $t = 10.0 \text{ s}$: no change in magnetic flux, $U_{\text{ind}} = \underline{\underline{0}}$

5. a) to d) see picture

a)  b)  d) 

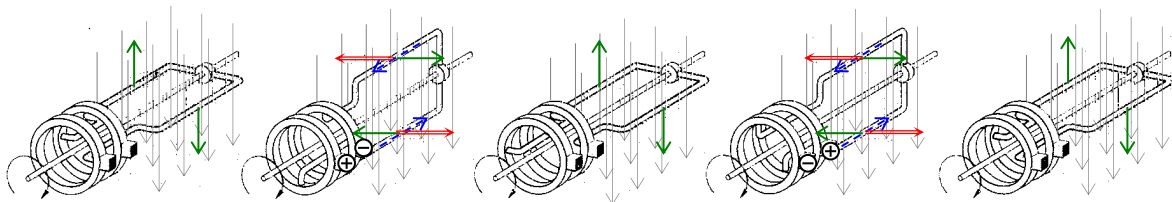
$t_1 = 0$

$t_2 = 5 \text{ ms}$

$t_3 = 10 \text{ ms}$

$t_4 = 15 \text{ ms}$

$t_5 = 20 \text{ ms}$



e) $T = \underline{\underline{20 \text{ ms}}}$

f) $f = \frac{1}{T} = \frac{1}{0.02 \text{ s}} = \underline{\underline{50 \text{ Hz}}}$

g) $\omega = 2\pi f = 2\pi \cdot 50 \text{ Hz} = \underline{\underline{314 \text{ s}^{-1}}}$

h) $\hat{U} = n \cdot A \cdot B \cdot \omega = 1 \cdot 0.0216 \text{ m}^2 \cdot 0.45 \text{ T} \cdot 314 \text{ s}^{-1} = \underline{\underline{3.05 \text{ V}}}$

i) $U_{\text{eff}} = \frac{\hat{U}}{\sqrt{2}} = \frac{3.05 \text{ V}}{\sqrt{2}} = \underline{\underline{2.16 \text{ V}}}$

- j) Lenz' law: A magnetic force acts upon the current in the loop of wire, opposite to the direction of the motion of the loop of wire.

$$6. \quad a) \quad \lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{28.79 \cdot 365 \cdot 24 \cdot 3'600 \text{ s}} = 7.6344 \cdot 10^{-10} \text{ s}^{-1}$$

$$A = \lambda \cdot N = 7.6344 \cdot 10^{-10} \text{ s}^{-1} \cdot 6.24 \cdot 10^{16} = \underline{4.76 \cdot 10^7 \text{ Bq}}$$

$$b) \quad N = N_0 \cdot e^{-\lambda \cdot t} \quad \frac{N}{N_0} = e^{-\lambda \cdot t} \quad \ln\left(\frac{N}{N_0}\right) = -\lambda \cdot t$$

$$t = \frac{\ln\left(\frac{N}{N_0}\right)}{-\lambda} = \frac{\ln\left(\frac{2.7 \cdot 10^{15}}{6.24 \cdot 10^{16}}\right)}{-7.6344 \cdot 10^{-10} \text{ s}} = \underline{4.11 \cdot 10^9 \text{ s}} = \underline{130 \text{ Jahre}}$$

$$7. \quad \lambda = \frac{\ln\left(\frac{A}{A_0}\right)}{-t} = \frac{\ln(0.88)}{-805'140 \text{ s}} = \underline{1.5877 \cdot 10^{-7} \text{ s}^{-1}}$$

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{1.5877 \cdot 10^{-7} \text{ s}^{-1}} = \underline{4'365'792 \text{ s}} \quad 4'365'792 \text{ s} = 50.53 \text{ d} \quad \underline{\text{Strontium-89}}$$