Exam Preparation: Electromagnetism, Electromagnetic Induction

Theory: Answer the questions and explain the concepts by heart

a) Vector/scalar
b) Give two examples of scalars
c) Give two 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) Energy
h) Voltage
i) Electric current
j) What is the purpose of electric current?
k) Elementary charge
l) Direct current/Alternating current
m) Magnetic field
n) Uniform field
o) What is the direction of the force acting on a charge moving perpendicular / parallel to a magnetic field?
p) Centripetal force
q) Explain Lenz' law

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			frequency		
period					

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
- represent vectors graphically by drawing them as arrows and solve problems by using this method
- 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 and vice versa
- 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

Exercises:

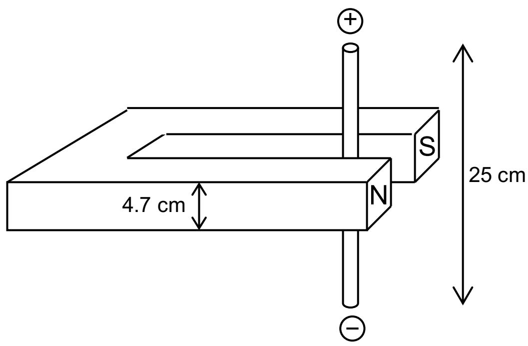
An algebraic solution and all values used in calculations are required to get the full mark.

All work sheets plus assignment sheets A57 – A58

Additional problems

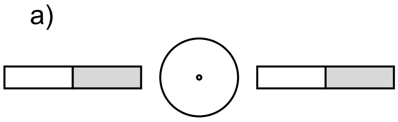
1. A wire of 0.08643900 km length is perpendicular to a magnetic field of 0.000210 mT. The force acting on the current is 1.67000 μN. The magnitude of the current is to be calculated.
a) Place a dot above the significant figures of the values which are required in the calculation. How many significant digits do they have? How many significant figures does your final answer require?
b) Calculate the magnitude of the current.
c) Round your results to the correct number of significant figures and write them in the normalized scientific notation (with a power of ten).

2. A current (I = 2.07 A) passes through a wire located between the poles of a horseshoe magnet. A force of 1.75 mN is acting on the electrons in the wire.
a) What is the direction of the magnetic force on the wire?
b) Calculate the magnetic field strength between the poles of the horseshoe magnet.

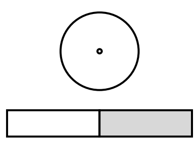


3. Here, electrons have been accelerated and are moving in a vacuum towards you. They strike a fluorescent screen which produces a luminous point. In the picture you can see the electrons that are moving directly towards you.
What direction are the electron deflected to?
Hint: First draw the magnetic field. (N  S).

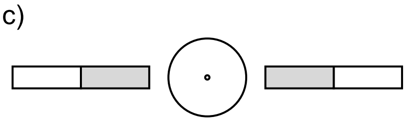
a)



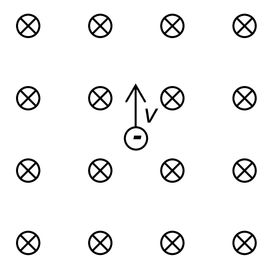
b)



c)



4. An electron was accelerated by a voltage of 45.0 V and is moving perpendicular to the field lines of a magnetic field of 1.85 mT. The magnetic field lines point into the paper, away from you.

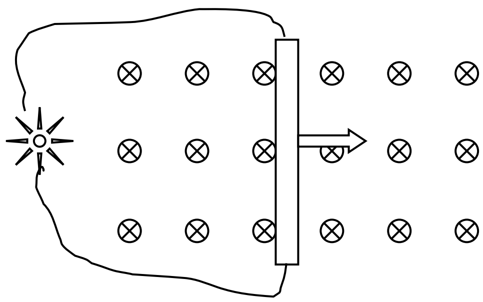


a) Draw in the picture the direction of the magnetic force as well as the path of the electron.
b) What is the kinetic energy of the electron?
c) What is the velocity of the electron?
d) What is the magnetic force acting on the electron?
e) Determine the radius of the electron's circular path.

5. A proton was accelerated to $1.53 \cdot 10^5 \frac{\text{m}}{\text{s}}$ and is moving perpendicular to the field lines of a magnetic field in a circular path of radius 7.41 cm.
Calculate the magnitude of the magnetic field.

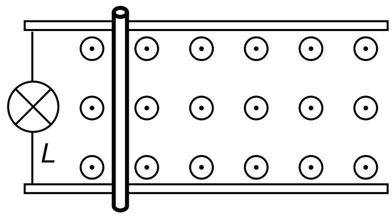
6. A proton was accelerated by a voltage of 260.0 V and is moving perpendicular to the field lines of a uniform magnetic field of 40.5 mT.
a) Determine the magnitude of the proton's velocity.
b) Calculate the radius of the proton's circular path.

7. A metal rod of length 20.0 cm is moved through a magnetic field (B = 0.12 T). The magnetic field lines point into the paper. The voltage between the two ends of the rod is 30.0 mV.



a) Label the positive and the negative side of the rod.
b) What is the velocity of the rod?
c) What is the current, if the two ends of the rod are connected with a wire and a current passes through a light bulb of resistance 0.40 Ω?
d) What is the force required for moving the rod to the right?
e) What is the power consumed by the light bulb?

8. A metal rod of 16.2 cm length is in a uniform magnetic field (B = 217 mT, the magnetic field lines point out of the paper). It is pushed to the right touching frictionlessly two metal rails with the constant velocity $4.30 \frac{\text{m}}{\text{s}}$ (see picture).



a) What is the induced voltage across the metal rod?
b) What is the induced current, if the resistance of the whole circuit is R = 0.87 Ω?
c) What is the direction of the electron flow? Draw it in the picture (whole circuit).
d) What is the force required for moving the rod?

9. Kevin is standing on the balcony and is holding a metal rod of 58.4 cm horizontally in East-West direction. Then he drops it from a height of 6.8 m. (Horizontal component of the magnetic field of the Earth is: $B = 2.06 \cdot 10^{-5}$ T, ignore air resistance.)
a) Which side of the rod will be charged negatively? Draw a sketch.
b) What is the voltage across the rod when it reaches the ground?

Solutions:

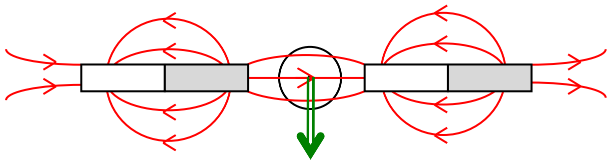
1. a) B = 0.000210 mT: 3 significant figures, ℓ = 0.0 8643900 km: 7 significant figures,
F = 1.67000 µN: 6 significant figures; result: 3 figures

b) $I = \frac{F}{\ell \cdot B} = \frac{1.67000 \cdot 10^{-6}\ \text{N}}{0.0864390 \cdot 10^{3}\ \text{m} \cdot 0.000210 \cdot 10^{-3}\ \text{T}} = 0.09199992\ \text{A} = \underline{\underline{0.0920\ \text{A}}}$

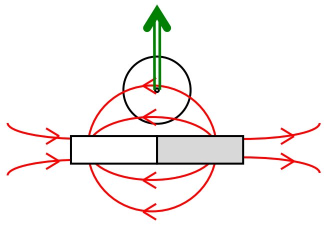
c) $\underline{\underline{9.20 \cdot 10^{-2}\text{A}}}$

2. a) to the right b) $B = \frac{F}{I \cdot s} = \frac{1.75 \cdot 10^{-3}\ \text{N}}{2.07\ \text{A} \cdot 0.047\ \text{m}} = 0.0180\ \text{T} = \underline{\underline{18.0\ \text{mT}}}$

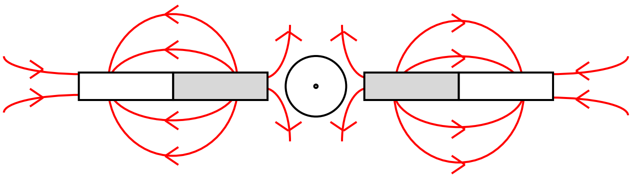
3. a)



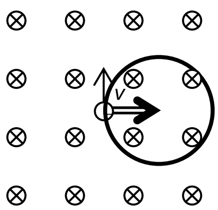
b)



c)



4. a)



b) $E_{kin} = W_{acceleration} = q \cdot U = 1\ \text{e} \cdot 45.0\ \text{V} = \underline{\underline{45.0\ \text{eV}}} = 1.6 \cdot 10^{-19}\ \text{C} \cdot 45.0\ \text{V}$
$= \underline{\underline{7.20 \cdot 10^{-18}\ \text{J}}}$

c) $v = \sqrt{\frac{2 \cdot E_{kin}}{m}} = \sqrt{\frac{2 \cdot q \cdot U}{m}} = \sqrt{\frac{2 \cdot 1.6 \cdot 10^{-19}\ \text{C} \cdot 45.0\ \text{V}}{9.11 \cdot 10^{-31}\ \text{kg}}} = \underline{\underline{3.98 \cdot 10^{6}\ \frac{\text{m}}{\text{s}}}}$

d) $F = q \cdot v \cdot B = 1.6 \cdot 10^{-19}\ \text{C} \cdot 3.96 \cdot 10^{6}\ \frac{\text{m}}{\text{s}} \cdot 1.85 \cdot 10^{-3}\ \text{T} = \underline{\underline{1.18 \cdot 10^{-15}\ \text{N}}}$

e) $F_{centripetal} = F_{magnetic}$ $\quad m \cdot \frac{v^2}{r} = q \cdot v \cdot B$

$$r = \frac{m \cdot v}{q \cdot B} = \frac{9.11 \cdot 10^{-31}\ \text{kg} \cdot 3.98 \cdot 10^{6}\ \frac{\text{m}}{\text{s}}}{1.6 \cdot 10^{-19}\ \text{C} \cdot 1.85 \cdot 10^{-3}\ \text{T}} = \underline{\underline{0.0122\ \text{m}}} = \underline{\underline{1.22\ \text{cm}}}$$

5. $B = \frac{m \cdot v}{q \cdot r} = \frac{1.67 \cdot 10^{-27}\ \text{kg} \cdot 1.53 \cdot 10^{5}\ \frac{\text{m}}{\text{s}}}{1.6 \cdot 10^{-19}\ \text{C} \cdot 0.0741\ \text{m}} = \underline{\underline{21.6\ \text{mT}}}$

6. a) $E_{kin} = W_{accelerating} = q \cdot U$

$$v = \sqrt{\frac{2 \cdot E_{kin}}{m}} = \sqrt{\frac{2 \cdot q \cdot U}{m}} = \sqrt{\frac{2 \cdot 1.6 \cdot 10^{-19}\ \text{C} \cdot 260\ \text{V}}{1.67 \cdot 10^{-27}\ \text{kg}}} = \underline{\underline{2.23 \cdot 10^{5}\ \frac{\text{m}}{\text{s}}}}$$

b) $r = \frac{m \cdot v}{q \cdot B} = \frac{1.67 \cdot 10^{-27}\ \text{kg} \cdot 2.23 \cdot 10^{5}\ \frac{\text{m}}{\text{s}}}{1.6 \cdot 10^{-19}\ \text{C} \cdot 40.5 \cdot 10^{-3}\ \text{T}} = 0.057\ \text{m} = \underline{\underline{5.7\ \text{cm}}}$

7. a) up: positive, down: negative

b) $v = \frac{U_{ind}}{B \cdot d} = \frac{0.030\text{ V}}{0.12\text{ T} \cdot 0.20\text{ m}} = \underline{\underline{1.25\ \frac{\text{m}}{\text{s}}}}$

c) $I = \frac{U_{ind}}{R} = \frac{0.030\text{ V}}{0.40\ \Omega} = \underline{\underline{75\text{ mA}}}$

d) $F = B \cdot I \cdot s = 0.12\text{ T} \cdot 0.075\text{ A} \cdot 0.20\text{ m} = \underline{\underline{1.8\text{ mN}}}$

e) $P = U \cdot I = 0.030\text{ V} \cdot 0.075\text{ A} = \underline{\underline{2.25\text{ mW}}}$

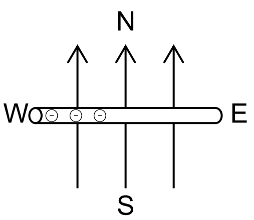
8. a) $U_{ind} = B \cdot v \cdot d = 0.217\text{ T} \cdot 4.30\ \frac{\text{m}}{\text{s}} \cdot 0.162\text{ m} = 0.151\text{ V} = \underline{\underline{151\text{ mV}}}$

b) $I = \frac{U}{R} = \frac{0.151\text{ V}}{0.87\ \Omega} = \underline{\underline{0.174\text{ A}}}$

c) counterclockwise

d) $F = B \cdot I \cdot s = 0.217\text{ T} \cdot 0.174\text{ A} \cdot 0.162\text{ m} = \underline{\underline{6.11\text{ mN}}}$

9. a)



Top view. The rod drops vertically down, into the paper. The geographic north pole of the earth is a magnetic south pole.

b) $v = \sqrt{2 \cdot g \cdot h} = \sqrt{2 \cdot 9.81\ \frac{\text{m}}{\text{s}^2} \cdot 6.8\text{ m}} = 11.6\ \frac{\text{m}}{\text{s}}$

$U_{ind} = B \cdot v \cdot d = 2.06 \cdot 10^{-5}\text{ T} \cdot 11.6\ \frac{\text{m}}{\text{s}} \cdot 0.584\text{ m} = \underline{\underline{0.139\text{ mV}}}$