Exam Preparation: Combustion Engines, Electrostatics

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) Charge
e) Characteristics of charges
f) Elementary charge
g) Electric current
h) Insulator: Give one or two materials that are insulators
Why do insulators not conduct electricity?
i) Polarisation
j) Conductor: Give one or two materials which are conductors
Why do conductors conduct electricity?
k) Electrostatic induction
l) Electric Field
m) Test charge
n) Electric field line
o) Uniform field
p) Definition of the direction of an electric field line
q) Electric field strength
r) What flows into the cylinder of a gasoline engine during the intake stroke?
s) What flows into the cylinder of a Diesel engine during the intake stroke?
t) How is ignition triggered in a gasoline engine?
u) How is ignition triggered in a Diesel engine?

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		
heat			charge		
electric current			electric field		

Skills:

- Transform equations, insert values including 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
- Convert the unit *Pascal* into *bar* and vice versa
- Convert units for area and volume
- Describe and explain the working principles of a two stroke gasoline engine, a four stroke gasoline engine and a four stroke Diesel engine. Label their different parts correctly.

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

Exercises:

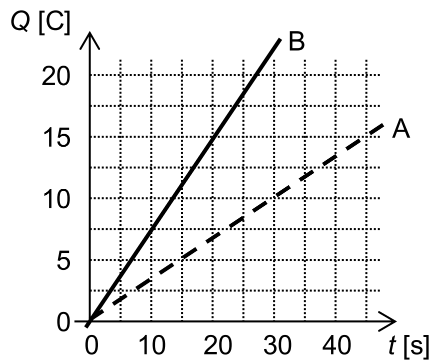
An algebraic solution and all values used in calculations are required to get the full mark.

All work sheets plus assignment sheets A44 – A47

Additional problems

1. An electric current of magnitude 0.0067800 A is flowing through the filament of a light bulb for 0.079300800 min.
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 amount of charge flowing through the light bulb and round your result to the correct number of significant figures.
c) Calculate the number of electrons flowing through the light bulb and round your result to the correct number of significant figures.
d) Write your results in the normalized scientific notation (with a power of ten).

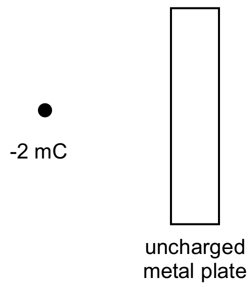
2. This graph shows how the amount of charge that passes through two different conductors A and B relates to the time elapsed.
a) Where is the electric current greater: in A or in B?
b) How much charge has passed through a cross section of wire B after 75 s?
c) Draw the graph for wire C carrying an electric current of 125 mA.



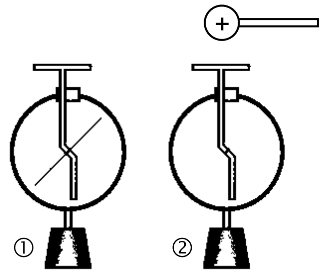
3. Sketch the field line patterns. Draw the charge distribution in the picture in case charges are separated by electrostatic induction.

a)

b)



4. Here's a negatively charged electroscope.
a) Draw the charge distribution in picture ①.
b) What happens, if a positively charged sphere approaches the head of the electroscope? Draw the position of the pointer as well as the charge distribution in picture ②.



5. Three insulated metal spheres of equal size carry charges: sphere A carries a charge of + 6.0 mC, sphere B carries a charge of – 3.0 mC, sphere C ist electrically neutral. Spheres A and C touch shortly and then are separated again. Afterwards spheres B and C touch shortly, and then are separated again.
   How much charge do the spheres A, B and C carry in the end?

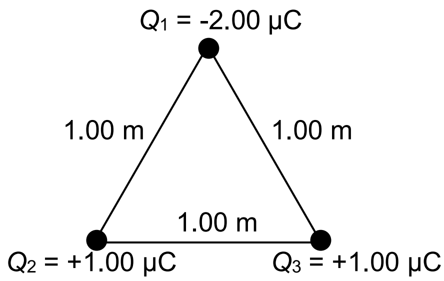
6. Two equal point charges are spaced 0.029960 m apart. They repel each other with the force 0.0400 mN. The magnitude of one of the point charges is to be calculated.
a) Place a dot above the significant figures of the values which are required in the calculation. How many significant digits do they have? How many significant figures does your final answer require?
b) Calculate the magnitude of one of the point charges.
c) Write your result it in the normalized scientific notation (with a power of ten) and rount it to the correct number of significant figures.

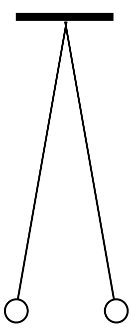
7. Two tiny metal spheres of the same size carry charges of + 10.0 nC und + 90.0 nC respectively and repel each other with a force of 1.26 mN. They are separated by the distance *r*.
   How far away from the smaller charge will a test charge be at equilibrium, if placed on a straight line between the two charges?

8. A proton is accelerated in a uniform electric field from 0 to 180'000.0 $\frac{\text{km}}{\text{h}}$ within 3.89 ms.
   Determine the magnitude of the electric field.

9. A drop of olive oil (r = 1.20 · 10^{-3} mm) carries three elementary charges and is hovering in the vertical uniform electric field between the horizontal plates of a capacitor.
   Determine the magnitude of the electric field between the plates.

10. *for ambitious folks only* Three charges are placed on the corners of a triangle (see picture to the right).
a) What's the magnitude of the force acting
   - between charges Q_1 and Q_2?
   - between charges Q_2 and Q_3?
   - between charges Q_1 and Q_3?
b) What's the magnitude and direction of the resultant forces acting on each one of the charges Q_1, Q_2 and Q_3?



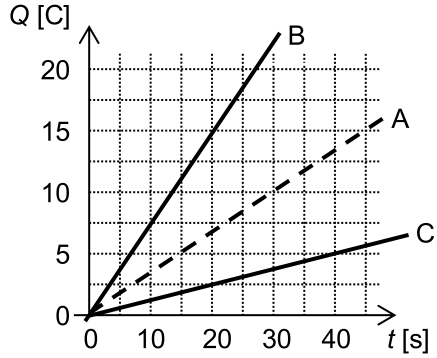
11. 

for ambitious folks only (difficult) Two equal spheres with a weight of $1.3 \cdot 10^{-2}$ N each are hanging on insulating threads with a length of 0.45 m, which are suspended from the ceiling in the same point (see picture to the left). They both carry equal charges. The centers of the spheres are 15 cm spaced apart.
Determine the charge of each sphere.

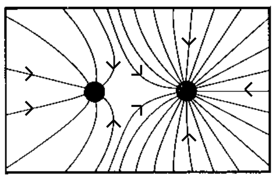
Solutions:

1. a) $t = 0.0\dot{7}\dot{9}\dot{3}\dot{0}\dot{0}\dot{8}\dot{0}\dot{0}$ min: 8; $I = 0.00\dot{6}\dot{7}\dot{8}\dot{0}\dot{0}$ A: 5; $e = \dot{1}.\dot{6}\dot{0}\dot{2} \cdot 10^{-19}$ C, 4, result: 5 for b) 4 for c)
   b) $Q = I \cdot t = 0.0067800 \text{ A} \cdot 0.079300800 \cdot 60 \text{ s} = 0.03225956554 \text{ C} = \underline{\underline{0.032260 \text{ C}}}$
   c) $\dfrac{0.03225956554 \text{ C}}{1.602 \cdot 10^{-19} \frac{\text{C}}{\text{electron}}} = 2.013705 \cdot 10^{17}$ electrons $= \underline{\underline{2.014 \cdot 10^{17} \text{ electrons}}}$
   d) $\underline{\underline{3.2260 \cdot 10^{-2} \text{ C}}}$ and $\underline{\underline{2.014 \cdot 10^{17} \text{ electrons}}}$

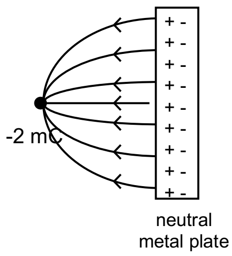
2. a) B (more charge is flowing during the same time)
   b) The electric current in B is
   $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{15 \text{ C}}{20 \text{ s}} = 0.75$ A , that is after 75 s the charge $\Delta Q = I \cdot \Delta t = 0.75 \text{ A} \cdot 75 \text{ s} = \underline{\underline{56.25 \text{ C}}}$ has passed through.
   c) If the current is 0.125 A, the charge passing through within 40 s is $\Delta Q = I \cdot \Delta t = 0.125 \text{ A} \cdot 40 \text{ s} = 5.0 \text{ C}$.
   Draw a straigh line through the point Q = 5C / t = 40 s



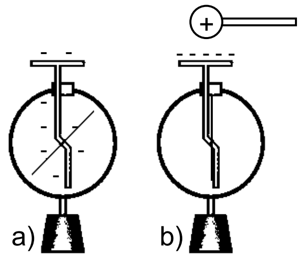
3. a)



b)



4.



5. 1. contact: A: + 3.0 mC, B: – 3.0 mC, C: + 3.0 mC
   2. contact: A: + 3.0 mC, B: 0 mC, C: 0 mC

6. a) $r = 0.0\dot{2}\dot{9}\dot{9}\dot{6}\dot{0}$ m : 5 significant digits, $F = 0.0\dot{4}\dot{0}\dot{0}$ mN: 3 significant digits,
   $\varepsilon_0 = \dot{8}.\dot{8}\dot{5}\dot{4}\dot{2} \cdot 10^{-12} \frac{\text{C}}{\text{V} \cdot \text{m}}$: 5 significant digits, result: 3 significant digits
   b) $F = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{Q_1 \cdot Q_2}{r^2} = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{Q^2}{r^2}$
   $Q = \sqrt{4 \pi \cdot \varepsilon_0 \cdot F \cdot r^2}$
   $= \sqrt{4\pi \cdot 8.8542 \cdot 10^{-12} \dfrac{\text{C}^2}{\text{N} \cdot \text{m}^2} \cdot 0.0400 \cdot 10^{-3} \text{ N} \cdot (0.029960 \text{ m})^2} = 1.998717 \cdot 10^{-9}$ C
   c) $\underline{\underline{2.00 \cdot 10^{-9} \text{ C}}}$

7. $r = \sqrt{\dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{Q_1 \cdot Q_2}{F}} = \sqrt{\dfrac{1}{4\pi \cdot 8.85 \cdot 10^{-12} \frac{\text{C}^2}{\text{Nm}^2}} \cdot \dfrac{10.0 \cdot 10^{-9} \text{ C} \cdot 90.0 \cdot 10^{-9} \text{ C}}{1.26 \cdot 10^{-3} \text{ N}}} = 0.0801 \text{ m} = 8.01 \text{ cm}$

$F_1 = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{Q \cdot Q}{r_1^2} = F_2 = \dfrac{1}{4\pi\varepsilon_0} \cdot \dfrac{Q \cdot 9Q}{r_2^2} \quad \Rightarrow \quad \dfrac{1}{r_1^2} = \dfrac{9}{r_2^2} \quad \Rightarrow \quad r_2^2 = 9 \cdot r_1^2$

$r_2 = 3 \cdot r_1$ $\qquad r_1 = \dfrac{1}{4} r =$ 2.0 cm from the smaller charge

8. $180'000\ \frac{\text{km}}{\text{h}} = 50'000\ \frac{\text{m}}{\text{s}}$ $v = a \cdot t$ $a = \frac{v}{t}$ $F = m \cdot a = m \cdot \left(\frac{v}{t}\right)$

$$E = \frac{F}{q} = \frac{m \cdot \left(\frac{v}{t}\right)}{q} = \frac{m \cdot v}{q \cdot t} = \frac{1.67 \cdot 10^{-27}\ \text{kg} \cdot 5.0 \cdot 10^{4}\ \frac{\text{m}}{\text{s}}}{1.602 \cdot 10^{-19}\ \text{C} \cdot 3.89 \cdot 10^{-3}\ \text{s}} = \underline{\underline{0.134\ \frac{\text{N}}{\text{C}}}}$$

9. Equilibrium of forces: $F_G = F_{el}$ $m \cdot g = q \cdot E$
substitute $q = 3 \cdot e$ and $m = \rho \cdot V = \rho \cdot \frac{4\pi}{3} \cdot r^3$

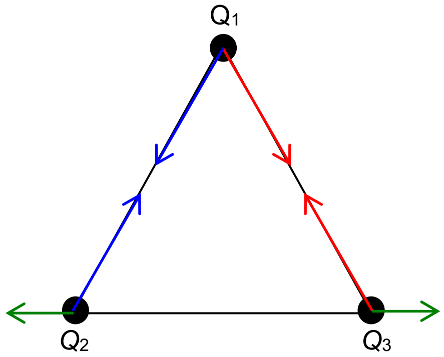
$$E = \frac{m \cdot g}{3e} = \frac{\rho \cdot \frac{4\pi}{3} \cdot r^3 \cdot g}{3e} = \frac{920\ \frac{\text{kg}}{\text{m}^3} \cdot \frac{4\pi}{3} \cdot \left(1.20 \cdot 10^{-6}\text{m}\right)^3 \cdot 9.81\ \frac{\text{m}}{\text{s}^2}}{3 \cdot 1.602 \cdot 10^{-19}\ \text{C}} = \underline{\underline{1.36 \cdot 10^{5}\ \frac{\text{N}}{\text{C}}}}$$

10. a) $$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1 \cdot Q_2}{r^2} = \frac{1}{4\pi \cdot 8.85 \cdot 10^{-12}\ \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}} \cdot \frac{2.0 \cdot 10^{-6}\ \text{C} \cdot 1.0 \cdot 10^{-6}\ \text{C}}{\left(1.00\ \text{m}\right)^2} = \underline{18\ \text{mN}}$$

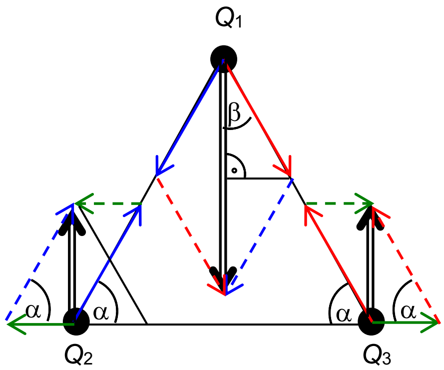
$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_2 \cdot Q_3}{r^2} = \frac{1}{4\pi \cdot 8.85 \cdot 10^{-12}\ \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}} \cdot \frac{1.0 \cdot 10^{-6}\ \text{C} \cdot 1.0 \cdot 10^{-6}\ \text{C}}{\left(1.00\ \text{m}\right)^2} = \underline{9.0\ \text{mN}}$$

$$F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Q_1 \cdot Q_3}{r^2} = \frac{1}{4\pi \cdot 8.85 \cdot 10^{-12}\ \frac{\text{C}^2}{\text{N} \cdot \text{m}^2}} \cdot \frac{2.0 \cdot 10^{-6}\ \text{C} \cdot 1.0 \cdot 10^{-6}\ \text{C}}{\left(1.00\ \text{m}\right)^2} = \underline{18\ \text{mN}}$$

b) Two forces are acting on each charge. The forces are sketched in a force diagram:



The forces need to be added vectorially. Let's form the resultant force which acts on each particle:



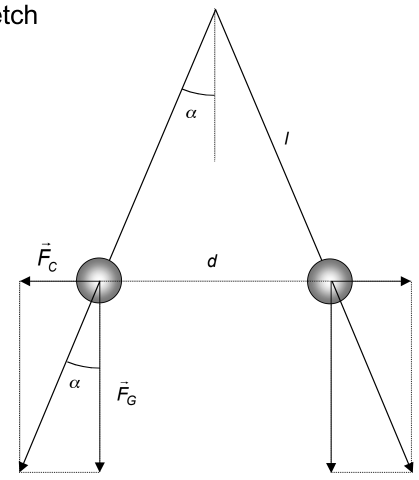
Force acting on Q_2 und Q_3: Since $F = 2 \cdot F$ and $\alpha = 60\ °$, the resultant force is the height of an equilateral triangle of side length F:

$$F_{res} = \frac{F}{2} \cdot \sqrt{3} = \frac{18\ \text{mN}}{2} \cdot \sqrt{3} = \underline{\underline{15.6\ \text{mN}}}$$

Force acting on Q_1: the resultant force is twice the adjacent of a right-angled triangle with hypothenuse F and the angle $\beta = 30\ °$:

$$F_{res} = 2 \cdot F \cdot \cos\beta = 2 \cdot 18\ \text{mN} \cdot \cos 30° = \underline{\underline{31.2\ \text{mN}}}$$

11. Sketch



Looking at the sketch we can see that

$\sin(\alpha) = \frac{\frac{d}{2}}{\ell}$ $\qquad$ $\alpha = \arcsin\left(\frac{\frac{d}{2}}{\ell}\right) = \arcsin\left(\frac{7.5\text{ cm}}{45\text{ cm}}\right) = 9.6\,°$

$\tan(\alpha) = \frac{F_c}{F_G}$ $\qquad$ $F_C = F_G \cdot \tan(\alpha) = 1.3 \cdot 10^{-2}\text{ N} \cdot \tan(9.6°) = 2.197 \cdot 10^{-3}\text{ N}$

$Q_1 = Q_2 = Q$ $\qquad$ $F_C = \frac{1}{4\pi \cdot \varepsilon_0} \cdot \frac{Q_1 \cdot Q_2}{d^2} = \frac{1}{4\pi \cdot \varepsilon_0} \cdot \frac{Q^2}{d^2}$

solving for Q yields:

$$Q = \sqrt{F_c \cdot 4\,\pi \cdot \varepsilon_0 \cdot d^2} = \sqrt{2.197 \cdot 10^{-3}\text{ N} \cdot 4\,\pi \cdot 8.85 \cdot 10^{-12}\,\frac{\text{C}^2}{\text{N}\cdot\text{m}^2} \cdot (0.15\text{ m})^2} = \underline{\underline{7.4 \cdot 10^{-8}\text{ C}}}$$