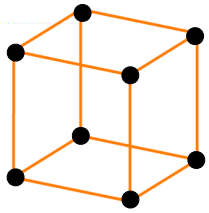
Electrodynamica — 15/6/2012

Om ambiguteit in terminologie te vermijden zijn de vragen in het Engels opgesteld. Als je bepaalde woorden of vragen in het Nederlands wilt vertaald krijgen kan je dit om het even wanneer komen vragen.

1. Give a *brief* answer to the following questions and *explain clearly and precisely* why your answer is correct:

   (a) Eight point charges of charge $+q$ are attached to the corners of a cube, as in this figure:

   Now add another, mobile point charge q. Is it possible to trap this particle somewhere in the electric field? More precisely, is there any point in space where the particle is in stable equilibrium? Is there a point where the particle is in unstable equilibrium?

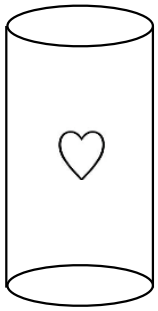
   (b) Is it possible to magnetically polarize a material such that the magnetic field points outwards everywhere on the boundary surface?

   (c) A lightbulb is placed in series with a capacitor and an AC voltage source. When the frequency of the AC voltage is increased, will the light get brighter or darker, or does nothing happen at all?

   (d) The image below shows a fish levitating between two poles of a strong magnet. The fish is stuck in stable equilibrium at a local minimum of the magnetic field strength. Explain this.

(e) A heart-shaped loop of superconducting wire is suspended inside an infinitely long solenoid. The heart is held perfectly vertical. A current is running through the wire of the heart. What is the electromotive force induced by the heart onto the solenoid?

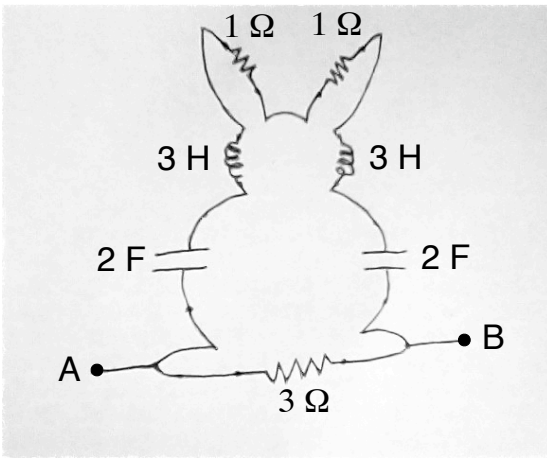


(f) A parallel plate capacitor is charged and disconnected. A block of dielectric material is partially inserted in the capacitor. Will the dielectric be pulled in or pushed out, or neither?

(g) Why is the sky blue, clouds white, and sunsets red?

(h) My sunglasses block horizontally polarized light. The sun is rising in the east and I am looking south. Does the sky look brighter or darker when I tilt my head to the right?

2. Consider the following circuit:



At time $t = 0$ the points A and B get connected to a 10 volt battery. What is the current through the upper and lower parts when $t \to \infty$? Optional extra credit problem (i.e. you will not lose points if you do not solve this and you might end up wasting time if you do): Compute the currents as a function of time assuming there were no currents for $t < 0$.

3. Consider the following electric and magnetic fields:

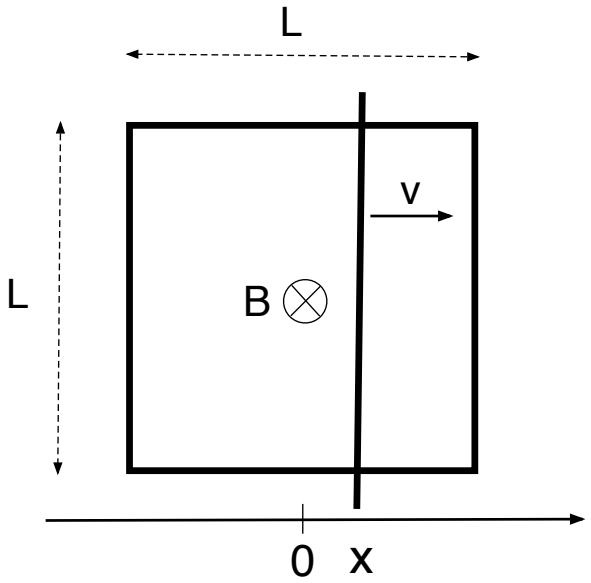
$$\begin{aligned} \boldsymbol{B} &= B_0\, xt\, \hat{\boldsymbol{y}} \\ \boldsymbol{E} &= (\alpha x^2 + \beta t^2)\hat{\boldsymbol{z}} \end{aligned}$$

Here B_0, α and β are constants and (x, y, z, t) are coordinates on space and time.

(a) For which values of α and β can this electromagnetic field exist in vacuum?

(b) Find the energy density and energy current of the field. Imagining a box around the origin, is energy flowing in or out of the box for $t > 0$?

4. A metal rod is allowed to slide without friction over a square metal wire frame as indicated in the figure. Let x be the position of the rod, with $x = 0$ corresponding to the midpoint. The square has edges of length L and the resistivity of the metal of which both rod and frame are made is ρ. There is a uniform, constant background magnetic field B perpendicular to the frame and pointing into the page. The cross sectional area of the rod and the frame wire equals A for both.



Imagine the rod is moving to the right with velocity v.

(a) Find the electromotive force $\mathcal{E}$ induced by the magnetic field acting on the charges in the rod.

(b) Find the current flowing through the rod (Hint: Model the system as a circuit where the edges of the frame are represented by resistors, and the moving rod by a resistor and voltage in series.)

(c) Find the force acting on the rod in the horizontal direction. Will it act to slow down or to accelerate the rod?

(d) Find the power dissipated by the currents and compare this to the work done per unit time by the horizontal magnetic force.

5. A particle of charge q is shot straight up from the surface of the earth with velocity v. How much energy is radiated away due to gravitational acceleration by the time it hits the earth again?