My way of understanding electromagnetism

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My way of understanding electromagnetism

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SUMMARY

It started almost 17 years ago. After having been working with antennas, transmission lines and all kinds of radio systems from the 1960´s I accepted to teach basic telecommunications and cellular systems at the KTH royal technical university in 1997.

When demonstrating transmission lines using slotted lines with electric and magnetic probes and directional couplers, and a simple time domain refectometer (TDR), it suddenly struck me that by increasing the resistor at the TDR-generator I should get the charging curve of the capacitor.

Of course it was a staircase showing the noise that hifi-entusiasts talk about when chosing capacitors for their audio projects.

When studying at the Chalmers University of Technology in 1967, at a lecture with professor Olof Rydbeck, founder of the Onsala space observatory, he said:

”I have been working with elektromagnetism all my live, but what is an electric field? What is a magnetic field?”

How do the fields combine into radiation?

Measurements with the slotted line showed points on the line where only a magnetic field or an electric field was visible, but the directional coupler indicated that radiation, both electric and magnetic fields, where present in all points.

Suppose we do it the other way around: What happens if there are no isolated electric or magnetic fields but only radiations? That was the beginning of this journey.

Chapter 3: First I checked with two of Maxwell´s equations and found that they are unnessary if we use radiations instead of fields.

Chapter 4: Then I made more experiments with the capacitor and discovered not only the staircase charging curve when the internal resistor of the voltage sourse is large, but also that there is a risk of overvoltage inside the capacitor if the internal resistor is low and the voltage is applied momentarely, as when mains power is switched on.

Chapter 5: I made experiments with the inductor, using shorted transmission lines.

Chapter 6: I explained the difference between E, D, H and B.

Chapter 7: Using the capacitor model with radiations to create the electric field, I expanded one plate to infinity and the other into a point creating a charged particle. Calculating the energy in the surrounded radiations and using numericals from the electron, the result showed that all energy associated with the mass of the electron is in the surrounding radiations.

Chapter 8: The next step was to show the location of the ”kinetic energy” in a moving electron.

Chapter 9: Now it was easy to calculate Ampère´s law from the radiation model of the electron.

Chapters 10 and 11: The next step was the potential energy and forces between particles, the electromagnetic force and the nuclear force. Being able to recognise the total energy in a group of particles (mass, kinetic and potential) gives a possibility to use the true definition of a force: Change in total energy with distance.

It started as a test to see what the result would be if all fields came from radiations, and ended with a physical model not based on particles as particle physics, but based entirely on radiations.

Älvsjö, August 20th, 2017

1. Maxwell's equations and Radiation

1.1 Symbols and formulas

(that I am using)

Electrical field strength: $E \quad [V/m]$

Magnetic field strength: $H \quad [A/m]$

Electric flux density: $D = \varepsilon \cdot E = \varepsilon_r \cdot \varepsilon_0 \cdot E \quad [As/m^2]$

Permittivity: $\varepsilon_0 \approx 8{,}854 \cdot 10^{-12} \approx \frac{1}{36\pi} \cdot 10^{-9} \quad [As/Vm]$

Magnetic flux density: $B = \mu \cdot H = \mu_r \cdot \mu_0 \cdot H \quad [Vs/m^2]$

Permeability: $\mu_0 = 4\pi \cdot 10^7 \quad [Vs/Am]$

Maxwell's equations:

$$\begin{cases} \nabla \cdot D = \rho \\ \nabla \cdot B = 0 \\ \nabla \times E = -\frac{\partial B}{\partial t} \\ \nabla \times H = J + \frac{\partial D}{\partial t} \end{cases}$$

Elektromagnetic (power) flux density (radiation): $S = E \times H \quad [W/m^2]$

Relation between E and H in elektromagnetic radiation: $Z = \frac{E_x}{H_y} = \sqrt{\frac{\mu}{\varepsilon}}$

Propagation velosity of electromagnetic radiation: $c = \sqrt{\frac{1}{\mu\varepsilon}} = \sqrt{\frac{1}{\mu_0\mu_r \cdot \varepsilon_0\varepsilon_r}} \approx \frac{1}{\sqrt{\mu_r \cdot \varepsilon_r}} \cdot 3 \cdot 10^8 \quad [m/s]$

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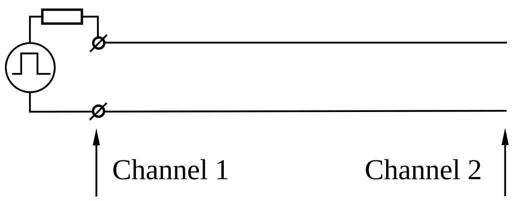
2. Fields from radiation

The Time Domain Reflectometer (TDR)

A TDR consists of a puls generator, a resistor usually 50 ohm and an oscilloscope.

With a dual channel oscilloscope we monitor the input signal and the output signal of a cable. We measure the time it takes for the signal to reach the end of the cable.



$$\frac{30.15\,m}{0.15\,\mu s} = 2\cdot 10^8\ m/s$$

For the coaxial cable the speed of the signal is calculated to 200 000 km/s which is 67% of the speed of electromagnetic radiation in vacuum, corresponding to radiation in a dielectric with $\varepsilon_r = 2.25$ which is the polythylene isolation between the center conductor and the screen.

$$\frac{13.3\,m}{0.05\,\mu s} = 2.66\cdot 10^8\ m/s$$

For the twin-lead the speed is 266 000 km/s, 87% which corresponds to radiation in a dielectric with $\varepsilon_r = 1.27$ which is the mixed isolation of air and plastic between the two conductors.

The speed of the signal?

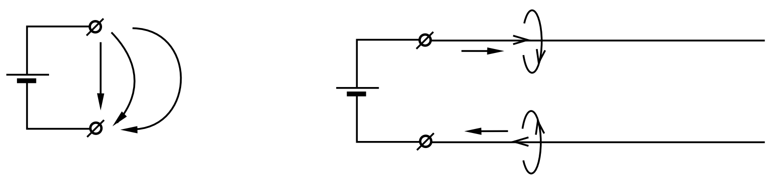
The signal on the transmission line is travelling with hte same speed as electromagnetic radiation in the space between the two conductors.

The speed depends on the dielectric properties of the insulating material.

2.1 Transmission lines

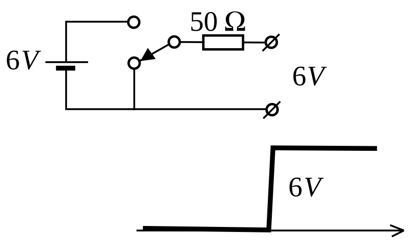
Radiation?

When a battery is connected to a transmission line there will be an electric field between the conductors, and also electric field components in the direction of the conductors. These field components will move charges in the conductors. There will be current in the conductors.

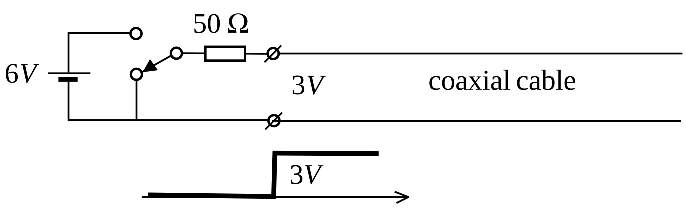


Let us measure the current.

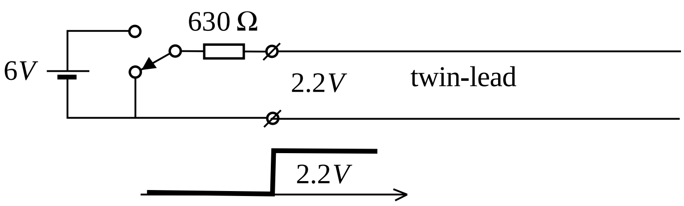
In our measurements the battery is 6 V as seen on the oscilloscope.



With the coaxial cable connected and a resistor of 50 ohm the voltage rise to 3 V across the cable. The cable looks like a 50 ohm resistor. The characteristic impedance of the cable is 50 ohm.

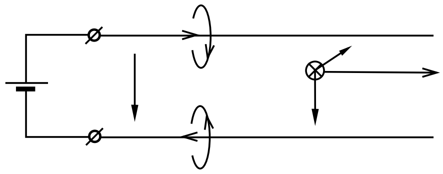


With the twin-lead and a resistor of 630 ohm the voltage rise to 2.2 V. This gives a characteristic impedance of 300 ohm.



The current in the conductors produce magnetic fields encircling the conductors.

The electric and magnetic fields are perpendicular representing electromagnetic radiation, which propagates along the transmission line.



How large will the current be?

The current will be exactly the value needed to produce the magnetic field strength H which gives electromagnetic radiation with the electric field strength E. The ratio between E and H is determined by the characteristic impedance Z_0 (actually Z_{medium}) of the medium (isolation) between the conductors.

$$Z_0\left[Z_{medium}\right]=\frac{E}{H} \quad \left(Z_0 \text{ in free space} = 377\ \Omega\right)$$

The field strengths are related to the voltage V and current I on the transmission line, and the ratio between the voltage and current Z_0 (actually Z_{line}) is the characteristic impedance Z_0 of the transmission line.

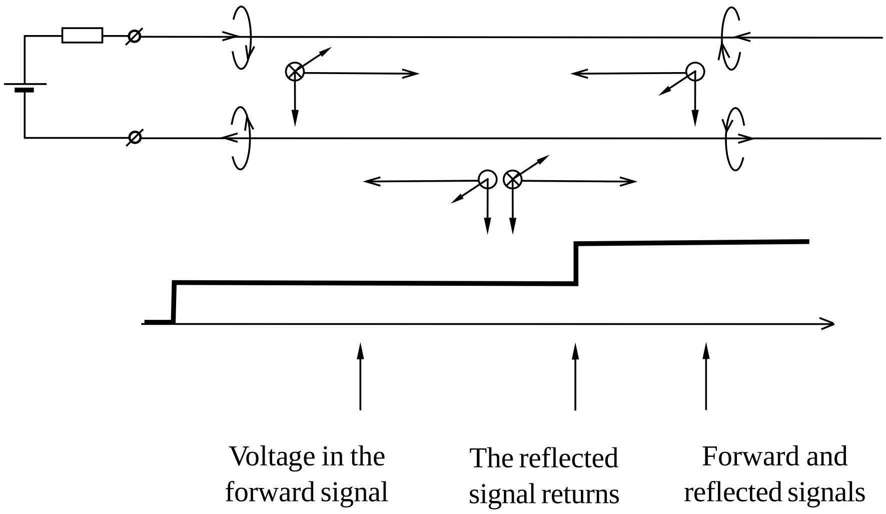
$$Z_0\left[Z_{line}\right]=\frac{V}{I} \quad \left(\mathrm{Z}_0 \text{ in a cable, i.e. } 50\ \Omega \text{ or } 300\ \Omega\right)$$

2.2 Current in an open transmission line?

Yes. When the forward going signal reaches the end of the transmission line, it is reflected back. What we usually see is the sum of the forward and reflected signals.

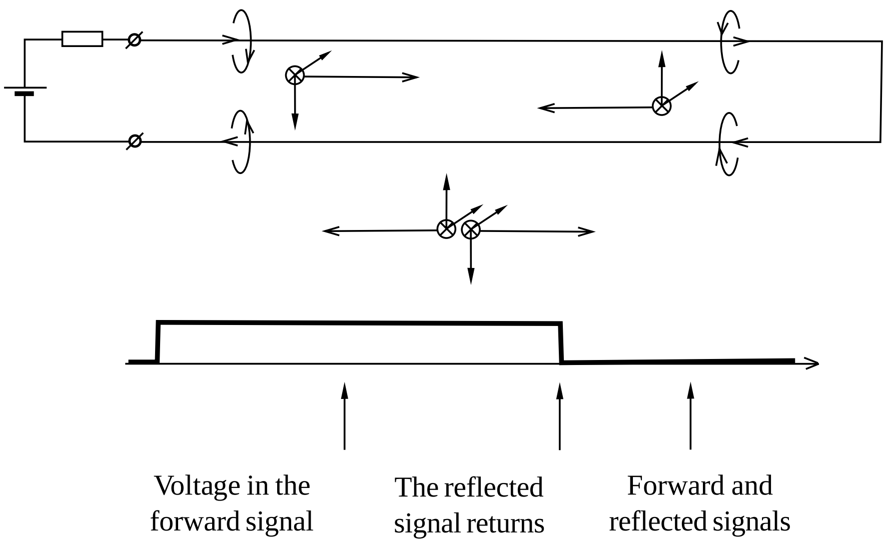
To avoid multiple reflections I have terminated the transmission line at the battery with its characteristic impedance.

Look how the currents cancel, and also the magnetic fields. What we see is the voltage between the conductors and the electric field.



In a shorted line?

In a shorted transmission line, the electric fields cancel, and what is left is the current in the conductors and the magnetic field.



2.3 The capacitor, a short open transmission line

The short transmission line looks like a capacitor.

If we increase the resistor our circuit should give the charging curve of the capacitor.

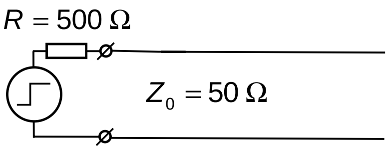
What we see on the oscilloscope is a staircase produced by the signal which is reflected at the far end, total reflection, but also being rereflected at the generator end according to the reflection coefficient.

Look at the picture. The first step is small. This is the voltage division between the resistor and the characteristic impedance of the cable.

The next step is larger because this is the first voltage comeing back plus the voltage that is rereflected back into the cable.

The charging curve looks noisy. There are reports of capacitors which are noisy when used in hi-fi audio applications.

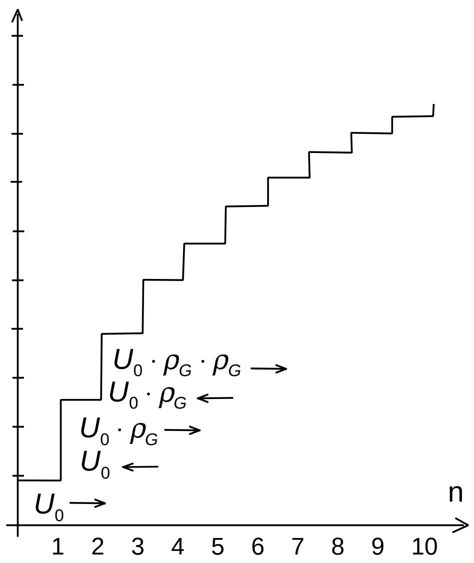
Yes. When the forward going signal reaches the end of the transmission line, it is reflected back. What we usually see is the sum of the forward and reflected signals.



$$U_0^+ = U \cdot \frac{Z_0}{R + Z_0}$$

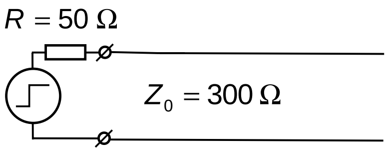
$$\rho_G = \frac{R - Z_0}{R + Z_0}$$

$$U_0 + U_0(1+\rho_G) + U_0(1+\rho_G)\rho_G + \cdots$$
$$\cdots + U_0(1+\rho_G)\rho_G^{n-1}$$



If the resistor is much smaller than the characteristic impedance of the capacitor?

In the example below the internal resistance of the generator is much smaller than the characteristic impedance of the line (capacitor).



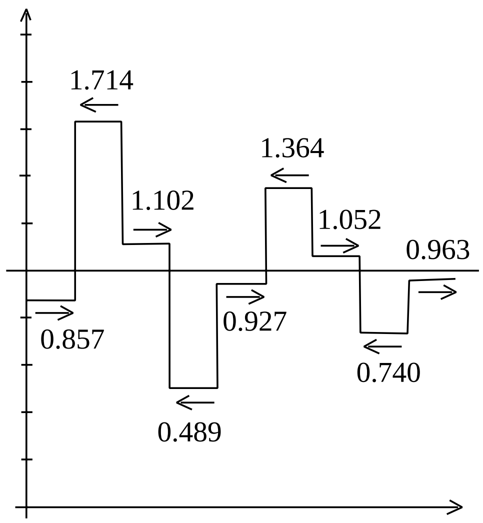
$$U_0^+ = U \cdot \frac{Z_0}{R+Z_0}$$

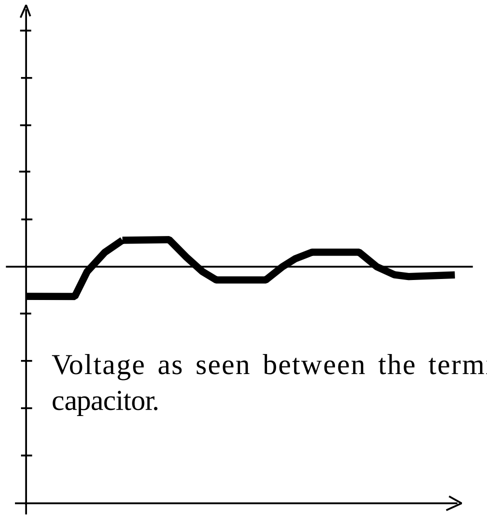
$$\rho_G = \frac{R-Z_0}{R+Z_0}$$

$$U_0 + U_0(1+\rho_G) + U_0(1+\rho_G)\rho_G + \cdots$$
$$\cdots + U_0(1+\rho_G)\rho_G^{n-1}$$

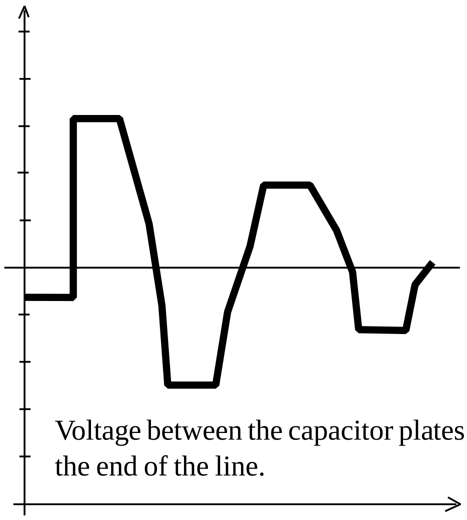
The first signal (voltage) going out on the line is 0.857 of the generator voltage. This signal is reflected and add to the forward signal which gives a total amplitude of 1,714 of the generator voltage between the conductors.

When this reflected signal reaches the line terminals it is rereflected back with a negative reflection coefficient. The voltage seen on the terminals is only 1.102 of the generator voltage, BUT the maximum voltage between the capacitor plates is almost twice the generator voltage.





Voltage as seen between the terminals of the capacitor.



Voltage between the capacitor plates as measured at the end of the line.

Pulses with extremely short rise time occur when power is switched on. They are also present in all types of switched power supplies, i.e. chargers for cellular phones.

It is important that capacitors in these applications can withstand voltages almost twice the generator voltage.

A switched power supply that rectify the mains voltage, in Europe 230 V RMS, 320 V peak, must have a ccapacitor that can withstand 640 V to avoid break down if it is connected to the mains supply exactly at the peak voltage, or it must have extra inductance in the mains leads to avoid short rise time when connected.

2.4 Measurements in a slotted line

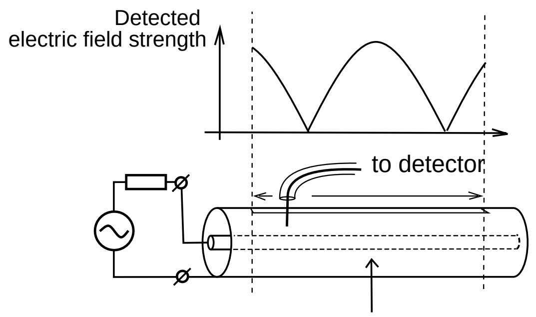
The slotted line has a slot in the screen. This slot does not affect the function of the cable but gives possibilities to insert a small probe in the space between the screen and the centre conductor of the cable.

To measure the electric or magnetic field, the probe or the fields must be changing. Both can not be fixed. We choose changing fields by using an AC signal from a 144 MHz generator.

A probe with a small antenna gives a signal that is proportional to the electric field.

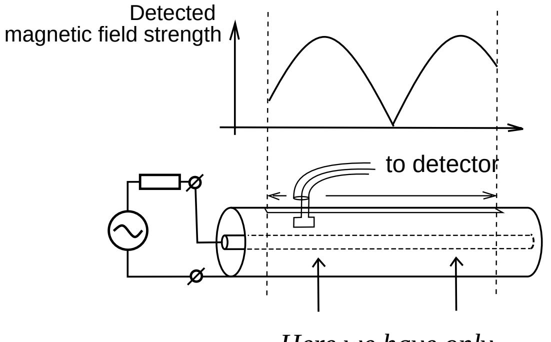
If the slotted line is terminated with 50 ohm there is no reflected signal and the field is constant along the line.

If the termination is removed the signal is reflected. We have two signals, one travelling forward, the other reflected. The probe will measure the sum of the electric fields. The reflected signal has travelled longer and in some points they add in phase, in other points out of phase, giving the familiar standing wave pattern. The maximum on the oscilloscope is twice the voltage, the sum of the electric fields, and the minimum is zero, when the electric fields are out of phase.



Here we have only electric field strength

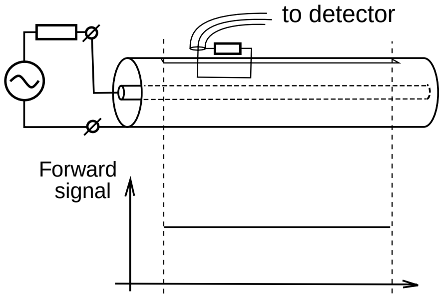
A probe with a loop gives a signal that is proportional to the magnetic fields. In the points with no electric field we have a maximum in the magnetic fields and vise versa.

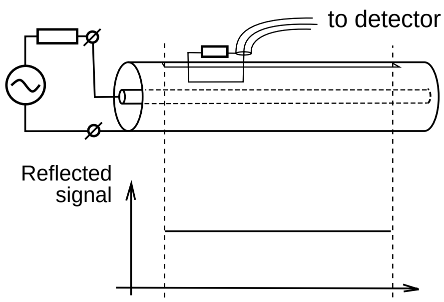


Here we have only magnetic field strength

2.5 Measurements with a directional coupler

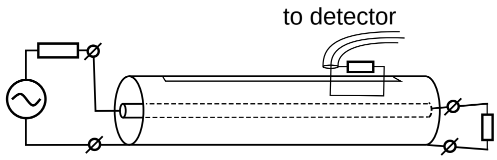
Today, measurements on transmission lines between transmitters and antennas are performed with ”directional couplers”, sensitive to the direction of the signal. With such directional couplers it is possible to independently measure the forward signal (the instrument is calibrated in forward power) and the reflected signal (the instrument is calibrated in reflected power). There is no need to move the detector (in a ”slotted line”) to obtain a reading.

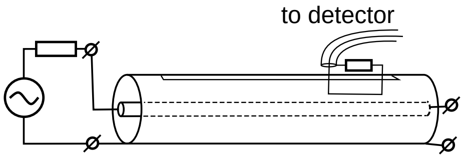


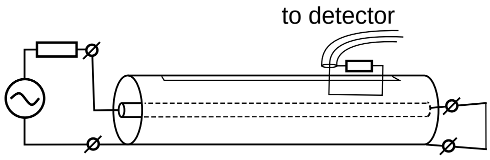


2.6 An experiment for my students

To convince my students that there are two signals, one in each direction, I use the following experiment:







With the caxial line terminated in its characteristic impedance, 50 ohm, we measured the forward signal on the line. The length of the line from the coupler to the termination was about 30 cm. Output from the coupler was viewed on an oscilloscope.

I asked my students: ”What happens on the oscilloscope if I disconnect the termination?”

Of course nothing happens. I measured the forward signal which had not yet been at the end of the line. The signal does not know what is happening further down the line.

Next I terminated the line with a short. Now we had a short circuit 30 cm from the coupler, and still nothing happend.

If we turn the coupler to measure reflected signal there happens a lot.

(This experiment can only be repeated if the internal impedance of the generator exactly matches the line. If multiple reflections occur the forward signal is not constant throughout these experiments.)

2.7 Summary

From the experiments with the slotted line we can learn:

1. Measuring with the E-field probe and with the H-field probe we find points on the line where the electric field is maximum and no magnetic field is visible.

2. In other points only the magnetic field is visible.

3. But in all points we have radiation of equal amplitude in both directions. The invisible fields are there but in antiphase.

Studying pulses on transmission lines with the TDR gives the same indikation:

4. A battery connected to an open transmission line gives only an electric field, but in the first moment when the battery is connected, when the ”capacitor” is charged, we have both electric and magnetic fields. When we reach ”steady state” the magnetic fields are of equal amplitude, in antiphase, and therefore invisible.

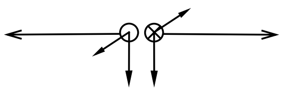
5. The same happens with a closed transmission line, a coil. During the charging of the coil we have both electric and magnetic fields. When we reach ”steady state” the electric fields are of equal amplitude, in antiphase, and therefore invisible.

I propose:

There are no such thing as isolated electric or magnetic fields, only radiation

An isolated electric field is always radiation in two or more directions, where the sum of the magnetic fields cancel and therefore are invisible for instruments detecting magnetic fields, and also invisible for matematicians.

An isolated magnetic field is always radiation in two or more directions, where the sum of the electric fields cancel and therefore are invisible.



In the chapters to follow we will test this hypothesis and arrive at some very interesting results.

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3. Fields from Radiation: Faraday's law, and Maxwell's addition to Ampère's lag

A radio engineer is used to working with forward and reflected signals and standing waves on cables, and concequently forward and reflected radiations and points with only electric or magnetic field strength in cables. Suppose we create electric and magnetic field strengths from radiation and test them on Faraday's law, and Maxwells complement to Ampère's law.

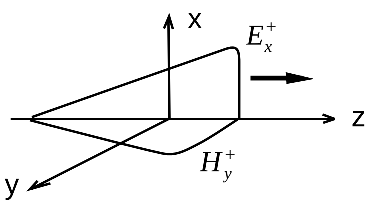
Create a time varying magnetic field from radiations. We need two radiations in opposit direction for the electric fields to cancel:

The first radiation

The first radiation is moving in positive z-direction with an amplitude equal to half of the electric field strength. This radiation consists of the following field strengths:

$$E_x^+ = \frac{E}{2}(x,z,t)$$

$$H_y^+ = \frac{H}{2}(y,z,t)$$

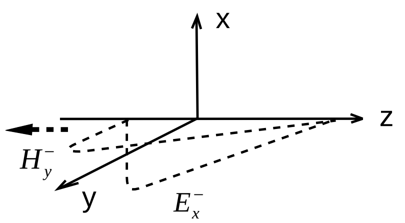


The second radiation

The second radiation is moving in negative z-direction with an amplitude equal to half of the electric field strength with the E-field in antiphase to the first radiation. This radiation consists of the following field strengths:

$$E_x^- = \frac{E}{2}(-x,-z,t)$$

$$H_y^- = \frac{H}{2}(y,-z,t)$$



3.1 Faraday's law

We want to start with: $\nabla \times E = \nabla \times \left(\frac{E^+}{2} + \frac{E^-}{2} \right) =$

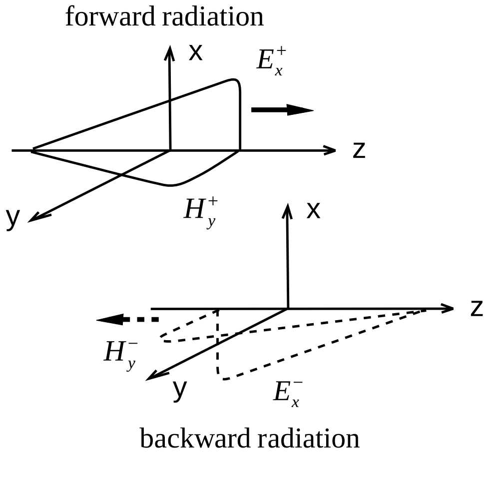
and the result should be: $= -\frac{\partial B}{\partial t}$

Calculate:

$$\nabla \times E = \nabla \times \left(E_x^+ + H_y^+ + E_x^- + H_y^- \right) = \begin{vmatrix} x & y & z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x^+ + E_x^- & H_y^+ + H_y^- & 0 \end{vmatrix} =$$

$$= \left[0 - \left(\frac{\partial H_y^+}{\partial z} + \frac{\partial H_y^-}{\partial z} \right) \right] x - \left[0 - \left(\frac{\partial E_x^+}{\partial z} + \frac{\partial E_x^-}{\partial z} \right) \right] y + \left[\left(\frac{\partial H_y^+}{\partial x} + \frac{\partial H_y^-}{\partial x} \right) - \left(\frac{\partial E_x^+}{\partial y} + \frac{\partial E_x^-}{\partial y} \right) \right] z =$$

Partial derivatives:



$$\begin{cases} E_x^+ = \frac{E}{2}(x, z, t) \quad \Rightarrow \quad \frac{\partial E_x^+}{\partial z} = \frac{\partial E}{2\partial z} \\ H_y^+ = \frac{H}{2}(y, z, t) \quad \Rightarrow \quad \frac{\partial H_y^+}{\partial z} = \frac{\partial H}{2\partial z} \\ E_x^- = \frac{E}{2}(-x, -z, t) \quad \Rightarrow \quad \frac{\partial E_x^-}{\partial z} = \frac{\partial E}{2\partial z} \\ H_y^- = \frac{H_y^-}{2}(y, -z, t) \quad \Rightarrow \quad \frac{\partial H_y^-}{\partial z} = -\frac{\partial H}{2\partial z} \\ \frac{\partial E_x^+}{\partial y} = \frac{\partial E_x^-}{\partial y} = \frac{\partial H_y^+}{\partial x} = \frac{\partial H_y^-}{\partial x} = 0 \end{cases}$$

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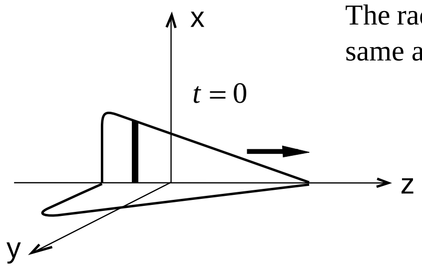
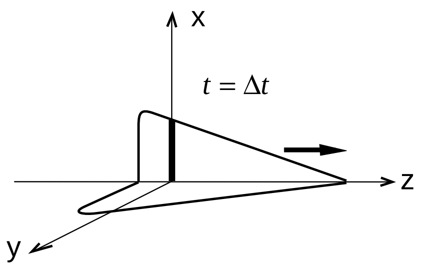
and use the derivatives:

$$=\left[0-\left(\frac{\partial H}{2\partial z}-\frac{\partial H}{2\partial z}\right)\right]x-\left[0-\left(\frac{\partial E}{2\partial z}+\frac{\partial E}{2\partial z}\right)\right]y+\left[(0+0)-(0+0)\right]z=\frac{\partial E}{\partial z}y$$



The radiation is moving. A value in another point on the z-axis is the same as staying in the original point but change the time:

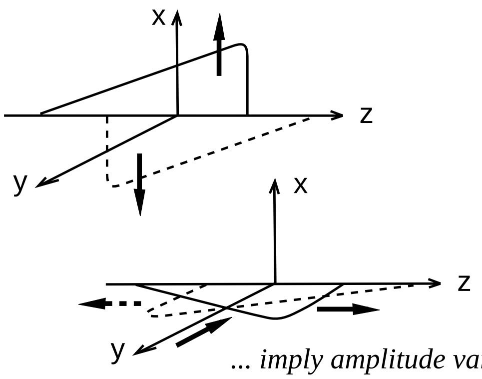


$$\begin{cases} -\Delta z = c\cdot\Delta t \quad \Rightarrow \quad -\dfrac{\partial}{\partial z}=\dfrac{1}{c}\cdot\dfrac{\partial}{\partial t}=\sqrt{\mu\varepsilon}\cdot\dfrac{\partial}{\partial t} \\ E=Z_0\cdot H=\sqrt{\dfrac{\mu}{\varepsilon}}\cdot H \end{cases}$$

Using this which is in the definition of radiation, we finaly get the time derivative of the magnetic flux density:

$$=\frac{\partial E}{\partial z}y=-\frac{1}{c}\cdot\frac{\partial E}{\partial t}y=-\frac{Z_0}{c}\cdot\frac{\partial H}{\partial t}y=-\sqrt{\mu\varepsilon}\cdot\sqrt{\frac{\mu}{\varepsilon}}\cdot\frac{\partial H}{\partial t}y=-\mu\cdot\frac{\partial H}{\partial t}y=-\frac{\partial B}{\partial t}y$$

rotation in the E-field strength ...



... imply amplitude variation in time for the magnetic field

Rotation in the electric field strength always imply a time varying magnetic flux density.

If we define electric field strength as a sum of radiations there is no need for Faraday's law. Faraday's law follows automatically.

3.2 Maxwell's addition to Ampère's law

This time we start with: $\nabla\times H=\nabla\times\left(\frac{H^+}{2}+\frac{H^-}{2}\right)=$

and the result should be: $=\frac{\partial D}{\partial t}$

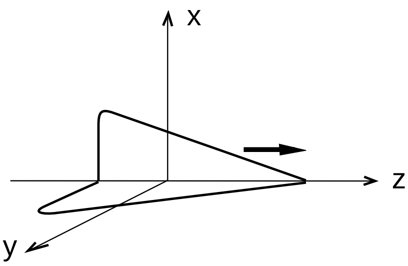
Create a time varying electric field from radiations:

The first radiation

The first radiation is moving in positive z-direction with an amplitude equal to half of the electric field strength. This radiation consists of the following field strengths, exactly as before:

$$E_x^+=\frac{E}{2}(x,z,t)$$

$$H_y^+=\frac{H}{2}(y,z,t)$$

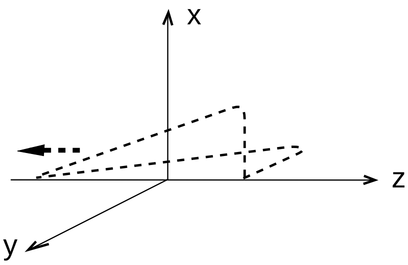


The second radiation

The second radiation is moving in negative z-direction with an amplitude equal to half of the electric field strength with the E-field in phase with the first radiation. This radiation consists of the following field strengths:

$$E_x^-=\frac{E}{2}(x,-z,t)$$

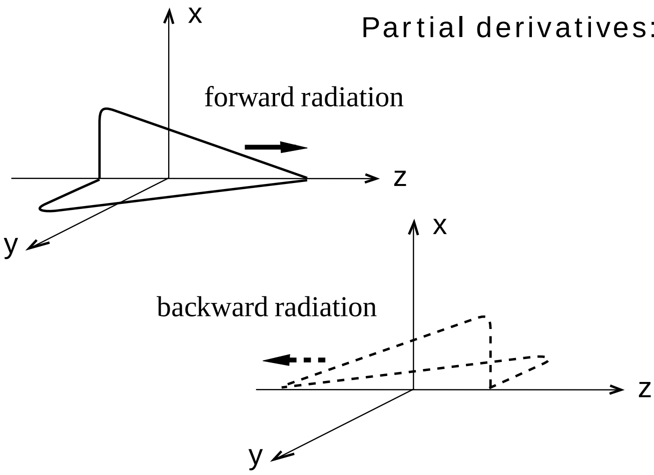
$$H_y^-=\frac{H}{2}(-y,-z,t)$$



Calculate:

$$\nabla\times H=\nabla\times\left(E_x^++H_y^++E_x^-+H_y^-\right)=\begin{vmatrix} x & y & z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x^++E_x^- & H_y^++H_y^- & 0 \end{vmatrix}=$$

$$=\left[0-\left(\frac{\partial H_y^+}{\partial z}+\frac{\partial H_y^-}{\partial z}\right)\right]x-\left[0-\left(\frac{\partial E_x^+}{\partial z}+\frac{\partial E_x^-}{\partial z}\right)\right]y+\left[\left(\frac{\partial H_y^+}{\partial x}+\frac{\partial H_y^-}{\partial x}\right)-\left(\frac{\partial E_x^+}{\partial y}+\frac{\partial E_x^-}{\partial y}\right)\right]z=$$



Partial derivatives:

$$\begin{cases} E_x^+ = \dfrac{E}{2}(x,z,t) \quad \Rightarrow \quad \dfrac{\partial E_x^+}{\partial z} = \dfrac{\partial E}{2\partial z} \\ H_y^+ = \dfrac{H}{2}(y,z,t) \quad \Rightarrow \quad \dfrac{\partial H_y^+}{\partial z} = \dfrac{\partial H}{2\partial z} \\ E_x^- = \dfrac{E}{2}(x,-z,t) \quad \Rightarrow \quad \dfrac{\partial E_x^-}{\partial z} = -\dfrac{\partial E}{2\partial z} \\ H_y^- = \dfrac{H_y^-}{2}(-y,-z,t) \quad \Rightarrow \quad \dfrac{\partial H_y^-}{\partial z} = \dfrac{\partial H}{2\partial z} \\ \dfrac{\partial E_x^+}{\partial y} = \dfrac{\partial E_x^-}{\partial y} = \dfrac{\partial H_y^+}{\partial x} = \dfrac{\partial H_y^-}{\partial x} = 0 \end{cases}$$

and use the derivatives:

$$= \left[0 - \left(\frac{\partial H}{2\partial z} + \frac{\partial H}{2\partial z}\right)\right] x - \left[0 - \left(\frac{\partial E}{2\partial z} - \frac{\partial E}{2\partial z}\right)\right] y + \left[(0+0) - (0+0)\right] z = -\frac{\partial H}{\partial z} x$$

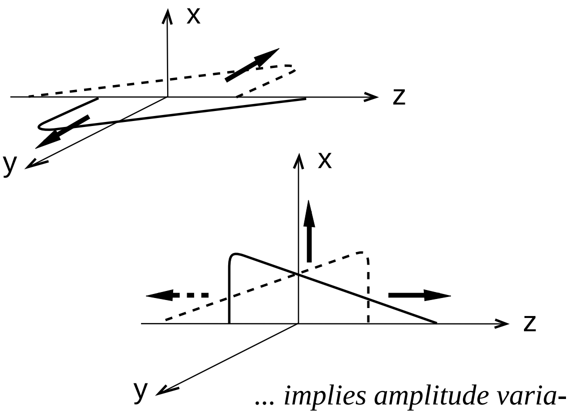
The radiation is moving. A value in another point on the z-axis is the same as staying in the original point but change the time:

$$\begin{cases} -\Delta z = c \cdot \Delta t \quad \Rightarrow \quad -\dfrac{\partial}{\partial z} = \dfrac{1}{c} \cdot \dfrac{\partial}{\partial t} = \sqrt{\mu\varepsilon} \cdot \dfrac{\partial}{\partial t} \\ H = \dfrac{E}{Z_0} = \sqrt{\dfrac{\varepsilon}{\mu}} \cdot E \end{cases}$$

Using this which is in the definition of radiation, we finaly get the time derivative of the magnetic flux density:

$$= -\frac{\partial H}{\partial z} x = \frac{1}{c} \cdot \frac{\partial H}{\partial t} x = \frac{1}{c \cdot Z_0} \cdot \frac{\partial E}{\partial t} x = \sqrt{\mu\varepsilon} \cdot \sqrt{\frac{\varepsilon}{\mu}} \cdot \frac{\partial E}{\partial t} x = \varepsilon \cdot \frac{\partial E}{\partial t} x = \frac{\partial D}{\partial t} x$$

rotation in the H-field strength ...



... implies amplitude variation in the electric field

Rotation in the magnetic field strength always imply a time varying electric flux density.

If we define magnetic field strength as a sum of radiations there is no need for Maxwell's complement of Ampère's law. This law follows automatically.

Conclusion

Faraday’s law and Maxwell’s addition to Ampere’s law implies that all fields are from radiations in different directions.

From this I propose:

There are no such thing as isolated electric or magnetic fields. The fields are always radiation.

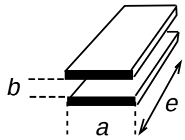
4. Fields from Radiation: The capacitor

4.1 Traditional view of the capacitor

The parallel plate capacitor

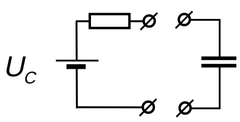
It is easy to calculate the capacitance of a parallel plate capacitor. We need the area $a \cdot e$, the capacitivity ε and the distance between the plates, b.

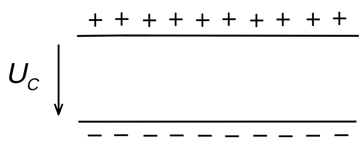
$$C = \varepsilon \cdot \frac{a \cdot e}{b} = \varepsilon_0 \varepsilon_r \cdot \frac{a \cdot e}{b}$$



Charge the capacitor

Connect a battery. We may have a resistor in series. Disconnect the battery when the capacitor is fully charged. Now there are charges on the plates.





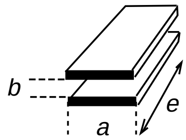
$$U_C = \frac{Q}{C}$$

Calculate the energy

Now we can calculate the energy stored in the capacitor.

$$W_C = \frac{1}{2} \cdot C \cdot U_C^2 = \frac{1}{2} \cdot \varepsilon_0 \varepsilon_r \cdot \frac{a \cdot e}{b} \cdot U_C^2$$

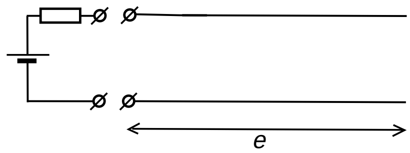
4.2 The transmission line as a capacitor



The parallel plate transmission line

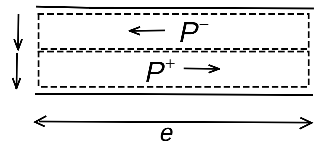
The parallel plate transmission line looks like a parallel plate capacitor. Connect the parallel plate transmission line to a battery. We get forward and reflected radiation between the plates. The electric field strengths E^+ and E^- add to a total electric field strength E , but the magnetic field strengths cancel.

When we have forward and reflected radiation on the line, the battery can be removed. Now there will be total reflection at the ends of the transmission line and the radiations will go back and forth in infinity.



$$\frac{U_C}{b} = E = E^+ + E^-$$

$$E^+ = E^- = \frac{U_C}{2b}$$



Forward and reflected radiations

We know the electric field strengths and can calculate forward and reflected power densities. Multiply with the area $a \cdot b$. Now we have forward power, and reflected power

$$S^+ = E^+ \times H^+ = E^+ \cdot \frac{E^+}{Z_{medium}} = E^+ \cdot \frac{E^+}{\sqrt{\frac{\mu}{\varepsilon}}} = \left(E^+\right)^2 \cdot \sqrt{\frac{\varepsilon}{\mu}} = \left(\frac{U_C}{2b}\right)^2 \cdot \sqrt{\frac{\varepsilon}{\mu}}$$

$$P^+ = S^+ \cdot ab = ab\left(\frac{U_C}{2b}\right)^2 \cdot \sqrt{\frac{\varepsilon}{\mu}} \qquad P^- = S^- \cdot ab = ab\left(\frac{U_C}{2b}\right)^2 \cdot \sqrt{\frac{\varepsilon}{\mu}}$$

Multiply with the time it takes to travel on the line, and we have total energy in the transmission line.

$$W = P^+ \cdot \Delta t + P^- \cdot \Delta t = 2 \cdot ab\left(\frac{U_C}{2b}\right)^2 \cdot \sqrt{\frac{\varepsilon}{\mu}} \cdot \frac{e}{c} = 2 \cdot ab\left(\frac{U_C}{2b}\right)^2 \cdot \sqrt{\frac{\varepsilon}{\mu}} \cdot \frac{e}{\frac{1}{\sqrt{\mu\varepsilon}}} = \frac{1}{2} \cdot \varepsilon \cdot \frac{a \cdot e}{b} \cdot U_C^2$$

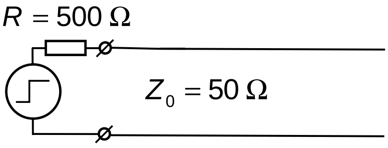
The charged ”capacitor” contains exactly the same amount of energy irrespective of which method is used: The capacitor as a container of charges, or the capacitor as a transmission line.

4.3 Charging the parallel plate line

Connect the parallel plate line to a voltage with amplitude *U* volt. What will the charging curve look like at the points of connection?

First there is voltage division

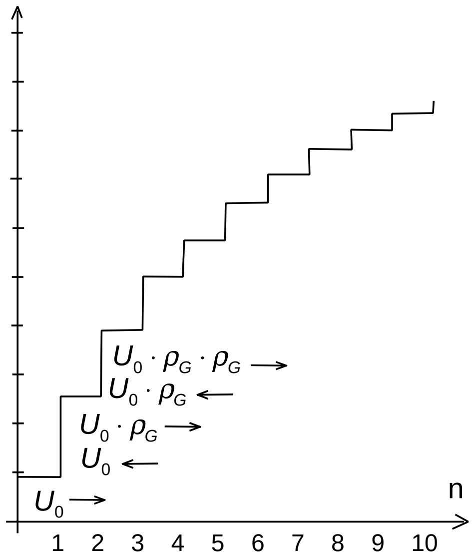
The voltage is divided between the resistor and the characteristic impedance Z_0 of the line. This voltage U_0 travels along the line, and is reflected totally (reflection coefficient +1 at the end of the line) and returns back after the time it takes to go forth and back on the line.



$$U_0^+ = U \cdot \frac{Z_0}{R+Z_0}$$

$$\rho_G = \frac{R-Z_0}{R+Z_0}$$

$$U_0 + U_0(1+\rho_G) + U_0(1+\rho_G)\rho_G + \cdots$$
$$\cdots + U_0(1+\rho_G)\rho_G^{n-1}$$



Reflexion coefficient at the ”generator”

When U_0 returns it hit the resistor in series with the generator. Let us calculate the reflection coefficient at the generator side of the line.

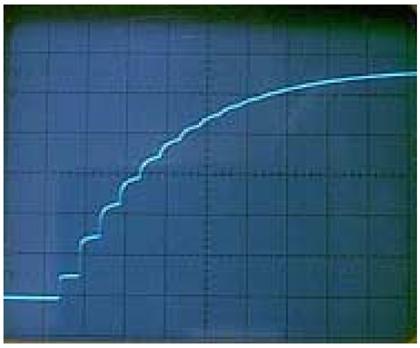
The first step on the charging curve is small, only the voltage division U_0. The next step is almost twice as high (the signal coming back from the line plus the reflected signal going out). This continues in infinity.

This will converge. Finally the sum of all forward signals are half of the battery voltage, and the reflected signals are the other half.

Measured with an oscilloscope

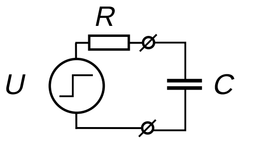
We used a pulse generator and studied the rising voltage on the oscilloscope. The resistance R was 500 ohm, the line was a 50 ohm coaxial cable 25 m long.

You see in the picture of the oscilloscope that the first step is about half of the next step, according to theory.



There will be some losses in charging the ”capacitor”. The front of the steps are rounded. This is due to attenuation in the cable at higher frequencies. But when the line is fully charged we have the same current from the forward signal as from the reflected signal. Total current is zero, and there are no losses from resistance in the conductors (capacitor plates).

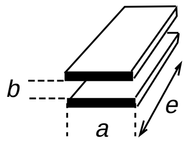
4.4 Charging the capacitor



$$U_C = U\left(1 - e^{-t/RC}\right)$$

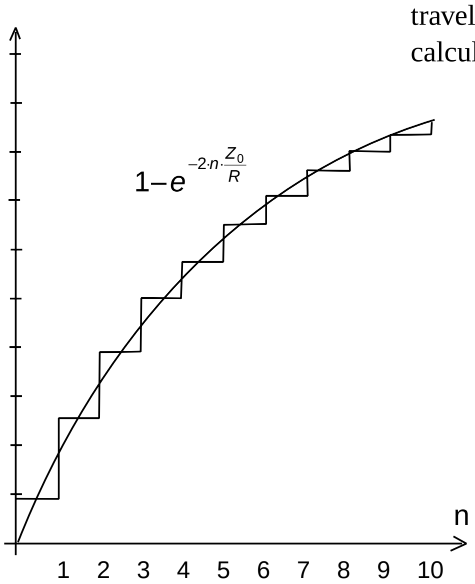
Calculate the traditional charging curve of the capacitor. To do this we need the ”capacitance” of our cable.

It is easy to derive a formula that only contains the characteristic impedance of the line and the time it takes to travel Δt_{line} (one way) on the line.



$$\begin{cases} C = \varepsilon \cdot \dfrac{a \cdot e}{b} \\ Z_0 = \dfrac{b}{a}\sqrt{\dfrac{\mu}{\varepsilon}} \end{cases} \qquad C = \varepsilon \cdot \frac{e\sqrt{\dfrac{\mu}{\varepsilon}}}{\dfrac{b}{a}\sqrt{\dfrac{\mu}{\varepsilon}}} = \frac{e\sqrt{\mu\varepsilon}}{Z_0} = \frac{e}{c} \cdot \frac{1}{Z_0} = \frac{\Delta t_{line}}{Z_0}$$

This is valid for all cables. A 50 ohm coaxial cable where the signal travels with 200 000 km/s has a capacitance of 100 pF/m. Now we can calculate the exponent of the e-funktion:



$$\frac{t}{RC} = \frac{t}{R\dfrac{\Delta t_{line}}{Z_0}} = \frac{n \cdot 2 \cdot \Delta t_{line}}{R\dfrac{\Delta t_{line}}{Z_0}} = 2 \cdot n \cdot \frac{Z_0}{R}$$

Use this for the e-function and express the time *t* in number of times (*n*) the signal has travelled forth and back on the line ($2 \cdot \Delta t_{line}$).

Sketch the well known charging curve for the capacitor. This is a good approximation of the steps from the capacitor as a short transmission line.

In an electrolytic capacitor the capacitivity of the dielectric is very high, which means that the speed of the signal is extremely low, and the stairs in the charging curve are large.

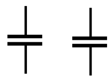
Watch out for high voltage between the capacitor plates

In some cases with charp steps of the voltage (at ”power on” or in switched power supplies) the voltage can reach almost twice the voltage of the source between the capacitor plates, as shown in the experiments with the TDR. The capacitor must be able to withstand this voltage without break down.

4.5 Two capacitors in parallell

Start with two identical capacitors. One is charged to the voltage U and get the charge Q. The other capacitor is uncharged. Total energy is the energy in the charged capacitor.

$Q = U \cdot C$ $\quad$ $Q = 0$

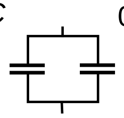
$U_C = U$  $U_C = 0$

$$W = \frac{1}{2}C \cdot U^2 + \frac{1}{2}C \cdot 0^2 = \frac{1}{2}C \cdot U^2$$

Connect the capacitors in parallell. The classical vieu is that the charges are shared between the capacitors. Charges can not disappear. Both capacitors get half of the charges, giving half of the voltage.

Calculate the total energy. Half of the energy is missing. Where did it go?

$0,5 \cdot Q = 0,5 \cdot U \cdot C$ $\quad$ $0,5 \cdot Q = 0,5 \cdot U \cdot C$

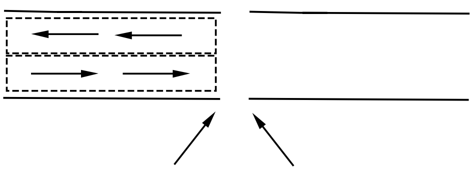
$U_C = 0,5 \cdot U$  $U_C = 0,5 \cdot U$

$$W = \frac{1}{2}C \cdot \left(\frac{U}{2}\right)^2 + \frac{1}{2}C \cdot \left(\frac{U}{2}\right)^2 = \frac{1}{4}C \cdot U^2$$

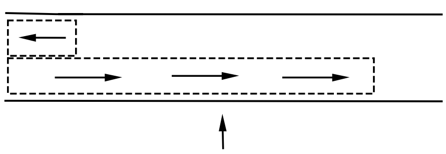
The capacitors as transmission lines

One capacitor is charged with forward and reflected power.

When the powers are equal, the currents in the capacitor plates are also equal. They pull on the electrons in both directions, and no electron is moving. Ohmic losses are from colliding electrons and radiation from accelerated or retarded electrons. If there are no moving electrons we have no losses and the forward and reflected power can travel in eternity.



Connect the capacitors. The power rush into the next capacitor and the currents are no longer equal. We get ohmic losses in the capacitor plates. The maximum power one source can deliver in the real ohmic world is half of its energy. That holds even here.



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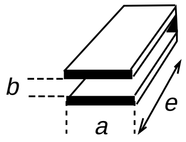
5. Fields from Radiation: The inductor

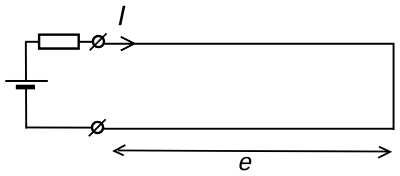
5.1 Traditional view of the inductor

Short the far end of the parallel plane transmission line and we have a one turn inductor. Calculate the inductance.



$$L = \mu \cdot \frac{b \cdot e}{a}$$

Calculate the energy stored in the inductor.

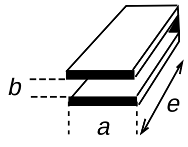


$$W_L = \frac{1}{2} \cdot L \cdot I^2 = \frac{1}{2} \cdot \mu \cdot \frac{b \cdot e}{a} \cdot I^2$$

5.2 The transmission line as an inductor

On the shorted transmission line we have forward and reflected signals as with the capacitor. The difference is that the reflection coefficient is -1 with the result that electric fields cancel and magnetic fields add.

Calculate the magnetic field strengths from Ampère's law:



$$H \cdot a + 0 \cdot a = I = \left(H^+ + H^-\right) \cdot a \quad \Rightarrow \quad H^+ = H^- = \frac{I}{2a}$$

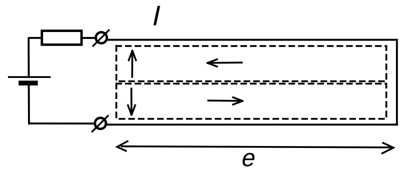
Forward and reflected radiations

When we know one of the field strengths we can calculate forward and reflected power densities on the line, and forward power and reflected power using the area $a \cdot b$.

$$S^{+} = E^{+} \times H^{+} = Z_{mediet} \cdot H^{+} \cdot H^{+} = \sqrt{\frac{\mu}{\varepsilon}}\left(H^{+}\right)^{2} = \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

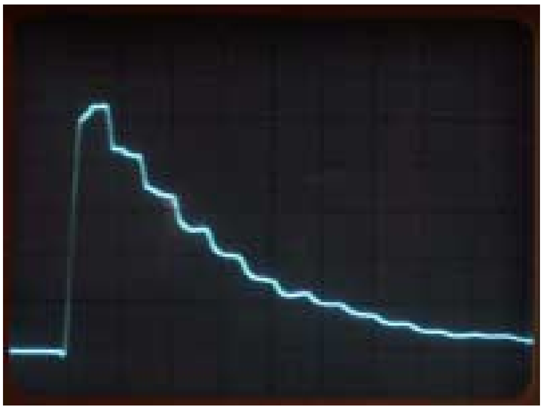
$$P^{+} = S^{+} \cdot ab = ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$P^{-} = S^{-} \cdot ab = ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$



Total energy in the line is, as with the capacitor:

$$W = P^{+} \cdot \Delta t + P^{-} \cdot \Delta t = 2 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \cdot \frac{e}{c} = 2 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \cdot \frac{e}{\frac{1}{\sqrt{\mu\varepsilon}}} = \frac{1}{2} \cdot \mu \cdot \frac{b \cdot e}{a} \cdot I^{2}$$



The energy in the inductor can be calculated either way, using the traditional formulas, or viewing the inductor as a transmission line.

The inductor is also charged as a staircase function

From a measurement, using a 50 ohm resistor and a shorted transmission line with 450 ohm characteristic impedance I got the photo of a nice staircase. The voltage is measured between the conductors at the connection point between the generator/resistor and the transmission line.

The speed of the radiations

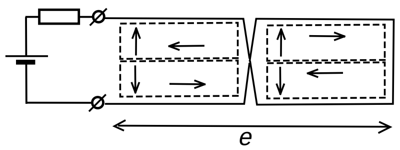
The traditional way of explaining an iron core in an inductor is that the iron molecules align themselves along the magnetic field and ”store” energy, equivalent to the dielectric molecules and the electric field in a capacitor.

In the transmission line model the capacitivity and permeability affect the speed of light. Radiation moves slower and more energy is stored in the same volume.

5.3 Mutual inductance

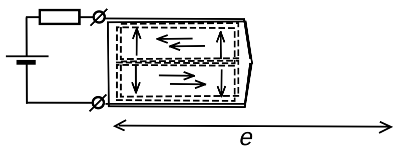
Start with a coil, looking like a shorted transmission line, but half way we twist the line a half turn. The forward signal twists its electric field uppside down, and the same for the reflected signal.

This will not change anything. We have two loops, half in size, but the total stored energy is unaffected.



$$L = \mu \cdot \frac{b \cdot e}{a} \qquad W_L = \frac{1}{2} \cdot L \cdot I^2 = \frac{1}{2} \cdot \mu \cdot \frac{b \cdot e}{a} \cdot I^2$$

Now bend the second loop and place it on top of the first loop. This gives a two turn loop half in size.



The new inductance is the sum of each ”half coil” plus the mutual inductance from coil 1 to 2, and the mutual inductance from coil 2 to 1.

$$L = L_1 + L_2 + L_{12} + L_{21} = \mu \cdot \frac{b \cdot \frac{e}{2}}{a} + \mu \cdot \frac{b \cdot \frac{e}{2}}{a} + \mu \cdot \frac{b \cdot \frac{e}{2}}{a} + \mu \cdot \frac{b \cdot \frac{e}{2}}{a} = 2 \cdot \mu \cdot \frac{b \cdot e}{a}$$

We can also use a standard formula saying that the inductance is proportional to the square of the number of turns in the coil.

$$L = \mu \cdot \frac{b \cdot \frac{e}{2}}{a} n^2 = \mu \cdot \frac{b \cdot \frac{e}{2}}{a} 2^2 = 2 \cdot \mu \cdot \frac{b \cdot e}{a}$$

This gives the stored energy:

$$W_L = \frac{1}{2} \cdot L \cdot I^2 = \frac{1}{2} \cdot 2 \cdot \mu \cdot \frac{b \cdot e}{a} \cdot I^2 = 2 \cdot \frac{1}{2} \cdot \mu \cdot \frac{b \cdot e}{a} \cdot I^2$$

As a transmission line

In the coil we have two radiations in each direction. With radiations in the same direction, we can not add power densities. We have to add field strengths.

The field strength in the sum of the signals going from left to right (LR) is twice as large giving a power density which is four times as large. So also with the signals going from right to left (RL).

$$S^{LR} = 2E^{LR} \times 2H^{LR} = Z_{mediet} \cdot 2H^{LR} \cdot 2H^{LR} = \sqrt{\frac{\mu}{\varepsilon}}\left(2H^{+}\right)^{2} = 4 \cdot \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

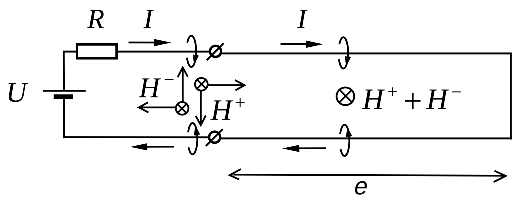
$$P^{LR} = S^{LR} \cdot ab = ab \cdot 4 \cdot \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$P^{RL} = S^{RL} \cdot ab = ab \cdot 4 \cdot \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$W = P^{LR} \cdot \Delta t_{e/2} + P^{RL} \cdot \Delta t_{e/2} = 2 \cdot 4 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \cdot \frac{\frac{e}{2}}{c} = 4 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \cdot \frac{e}{\frac{1}{\sqrt{\mu\varepsilon}}} = 2 \cdot \frac{1}{2} \cdot \mu \cdot \frac{b \cdot e}{a} \cdot I^{2}$$

The one-turn loop

In the one-turn loop we have the current *I* calculated from *U/R*.



From Ampères law we calculate the total magnetic field strength, and this field strength we divide into forward and reflected radiation densities.

$$H\cdot a + 0\cdot a = I = \left(H^{+} + H^{-}\right)\cdot a \quad \Rightarrow \quad H^{+} = H^{-} = \frac{I}{2a}$$

$$S^{+} = E^{+}\times H^{+} = Z_{medium}\cdot H^{+}\cdot H^{+} = \sqrt{\frac{\mu}{\varepsilon}}\left(H^{+}\right)^{2} = \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

Next we calculate forward and reflected radiation, and from there the total (magnetic) energy in the one-turn loop.

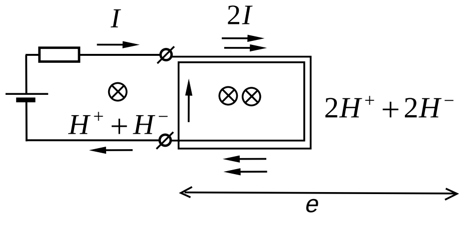
$$P^{+} = S^{+}\cdot ab = ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \qquad P^{-} = S^{-}\cdot ab = ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$W = P^{+}\cdot\Delta t + P^{-}\cdot\Delta t = 2\cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}\cdot\left[\frac{e}{c}\right]$$

The two-turn loop

If we make a two-turn loop of the same wire, we have the same current in each wire, giving $2\cdot I$ in Ampères law, and the magnetic field strength is twice as large. This gives radiation intensities inside the loop that is four times as large.

This loop is only half in size, but the total energy is two times as large.



$$S^{+} = 2E^{+}\times 2H^{+} = Z_{medium}\cdot 2H^{+}\cdot 2H^{+} = \sqrt{\frac{\mu}{\varepsilon}}\left(2H^{+}\right)^{2} = 4\cdot\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$P^{+} = S^{+}\cdot ab = 4\cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \qquad P^{-} = S^{-}\cdot ab = 4\cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$W = P^{+}\cdot\Delta t_{e/2} + P^{-}\cdot\Delta t_{e/2} = 2\cdot 4\cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}\cdot\frac{\frac{e}{2}}{c} = 4\cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}\cdot\frac{e}{c}$$

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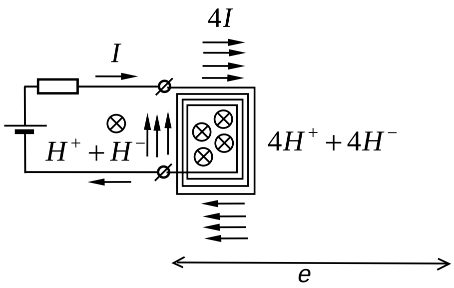
The four-turn loop

If the wire is arranged in a four-turn loop we still have the same current in each wire, giving $4 \cdot I$ in Ampères law, and the magnetic field strength is four times as large. This gives radiation intensitiy inside the loop that is four times as large.

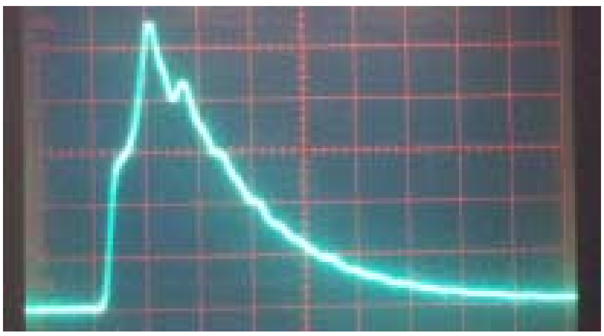
This loop is only one quarter in size, but the total energy is four times as large.

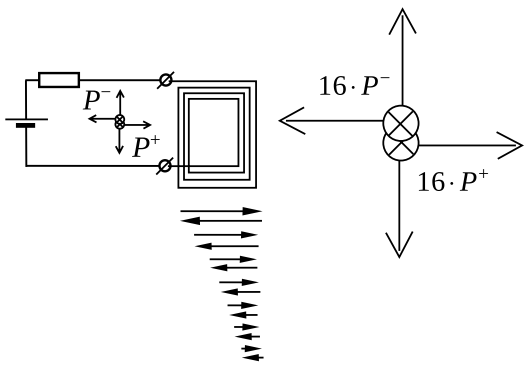


$$S^{+} = 4E^{+} \times 4H^{+} = Z_{medium} \cdot 4H^{+} \cdot 4H^{+} = \sqrt{\frac{\mu}{\varepsilon}}\left(4H^{+}\right)^{2} = 16 \cdot \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$P^{+} = S^{+} \cdot ab = ab \cdot 16 \cdot \sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \qquad P^{-} = S^{-} \cdot ab = 16 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2}$$

$$W = P^{+} \cdot \Delta t_{e/4} + P^{-} \cdot \Delta t_{e/4} = 2 \cdot 16 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \cdot \frac{\frac{e}{4}}{c} = 8 \cdot ab\sqrt{\frac{\mu}{\varepsilon}}\left(\frac{I}{2a}\right)^{2} \cdot \frac{e}{c}$$



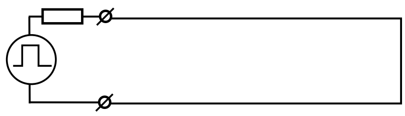


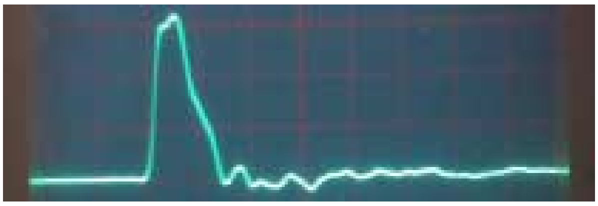
How can the radiations be 16 times as large inside the loop?

When the radiation enters the loop, some part is reflected, but radiation will continue to enter the loop and be reflected back and forth until the boundary conditions are fulfilled. With 4 turns in the loop, the current must be 4 times as large (ideal conditions without losses and 100% coupling between the turns). This results in very large electric fields, but that does not matter. They are in antiphase, as are the electric fields in the incident radiation. Boundary conditions are fulfilled for the electric fields as well.

Voltage at the terminals of a one-turn coil

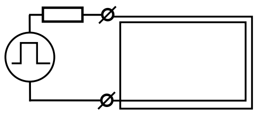
The area shows energy going into the coil.

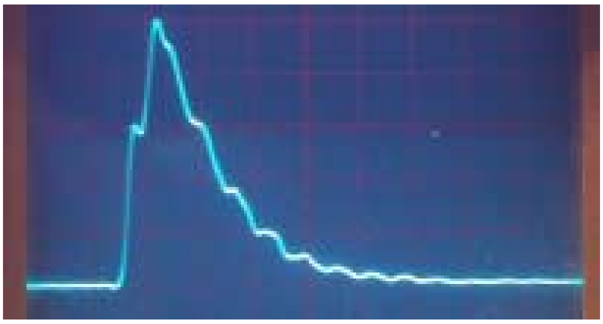




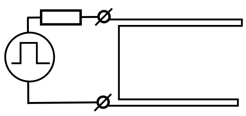
Voltage at the terminals of a two-turn coil

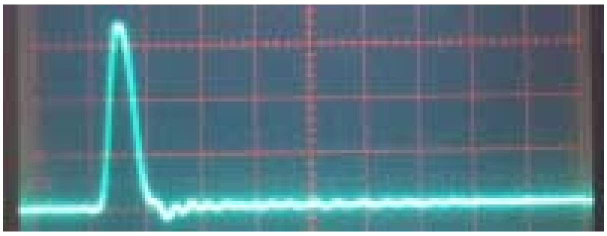
This picture shows energy going into the coil. The area represents the total energy stored in the coil.





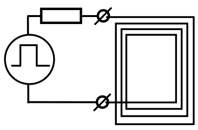
The next picture shows what happens when the turns in the coil are arranged in antiphase. Energy goes in, but is immediately reflected back.

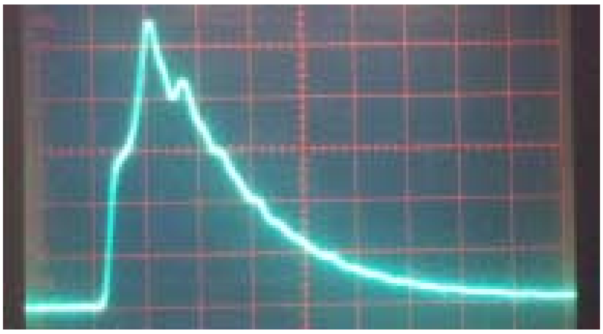




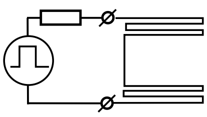
Voltage at the terminals of a four-turn coil

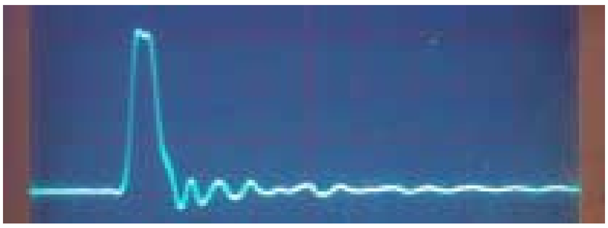
Now the area is larger. More energy is stored in the coil.





Here the turns are in antiphase. Energy goes in, but is immediately reflected back.





6. Fields from Radiation: E and D, H and B

6.1 *E* and *D*, *H* and *B*

A lot of textbook authors have difficulties how to handle E, D, H and B. Sometimes they put E and B in one group, and D together with H.

E and *H* is always radiation

E is the electric field strength and H is the magnetic field strength in a radiation which has the power density *S*. The ratio between E and H is always determined by the medium, its characteristic impedance.

$$S = E \times H \quad \left[W / m^2 \right]$$

$$Z = \frac{E_x}{H_y} = \sqrt{\frac{\mu}{\varepsilon}}$$

$$c = \frac{1}{\sqrt{\mu \cdot \varepsilon}}$$

If we have an E-field this is an indication that there is radiation, and we must also have the corresponding H-field.

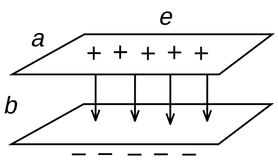
If the ratio between E and H differs from the characteristic impedance of the medium, this is an indication of multiple radiations in different directions.

Total energy in a volume

To calculate the total energy in a volume we must know the power entering the volume and the time it takes to fill the volume.

$$W = S \cdot ab \cdot t = S \cdot ab \cdot \frac{e}{c}$$

$$W = S \cdot ab \cdot \frac{e}{c} = S \cdot abe \cdot \frac{1}{\frac{1}{\sqrt{\mu \cdot \varepsilon}}} = S \cdot abe \cdot \sqrt{\mu \cdot \varepsilon}$$



$$W = E \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = E \cdot \frac{E}{Z} \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = E \cdot \frac{E}{\sqrt{\frac{\mu}{\varepsilon}}} \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = E \cdot \varepsilon E \cdot abe = E \cdot D \cdot abe$$

$$W = E \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = Z \cdot H \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = \sqrt{\frac{\mu}{\varepsilon}} \cdot H \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = \mu H \cdot H \cdot abe = B \cdot H \cdot abe$$

These simple calculations show that *D* and *B* tale care of the correction factor for the speed of the radiation.

Engineering constants

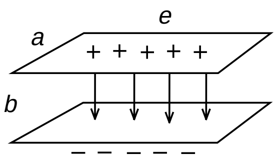
The constants μ and ε are from the first experiments with capacitors and inductors before and after the year 1800. In 1864 Maxwell linked these constants to the speed of electromagnetic radiation. Now I link electromagnetic radiation to capacitors and inductors.

To calculate the total energy in a capacitor we have not one but two radiations, going back and forth, and arrive at the familiar formula:

$$W = \frac{E}{2} \cdot \varepsilon \frac{E}{2} \cdot abe + \frac{E}{2} \cdot \varepsilon \frac{E}{2} \cdot abe = \frac{1}{2} \varepsilon \cdot E^2 \cdot abe = \frac{1}{2} E \cdot D \cdot abe$$

6.2 *D* at a ”surface”

When we calculate the total amount of charge Q on the plates of the capacitor, it is not enough to know the electric field strength between the plates. We must also know the density of the lines, or talking radiation, we must know the speed of the radiation going back and forth in the space between the plates.



The charge Q is a description of the energy in the space between the capacitor plates. We must have a three dimensional description of the electric field lines, and the electric flux density D is such a three dimensional description that takes care of the speed of the radiations.

We get $c = \frac{1}{\sqrt{\mu \cdot \varepsilon}} = \frac{1}{\sqrt{\mu_0 \cdot \varepsilon_0}} \cdot \frac{1}{\sqrt{\mu_r \cdot \varepsilon_r}} = c_0 \cdot \frac{1}{\sqrt{1 \cdot \varepsilon_r}}$

$$Q = C \cdot U_C = \varepsilon \cdot \frac{a \cdot e}{b} \cdot U_C = \varepsilon \frac{U_C}{b} a \cdot e = \varepsilon E \cdot a \cdot e = D \cdot a \cdot e = \varepsilon_0 E \cdot a\sqrt{\varepsilon_r} \cdot e\sqrt{\varepsilon_r}$$

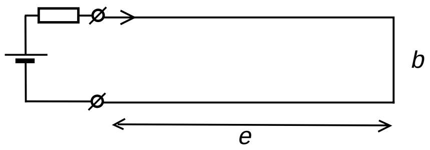
With a dielectric the speed of the radiation is slower. This is equivalent to a larger area of the capacitor plates:

$$a\sqrt{\varepsilon_r} \cdot e\sqrt{\varepsilon_r}$$

Observe that *b* is unaffected. The radiation is not moving in that direction.

6.3 Magnetic flux density *B*

Exactly the same happens when we calculate the total number of magnetic field lines passing through a loop. We use the magnetic flux density B:



Speed of the radiation with a magnetic medium in the loop:

$$c = \frac{1}{\sqrt{\mu \cdot \varepsilon}} = \frac{1}{\sqrt{\mu_0 \cdot \varepsilon_0}} \cdot \frac{1}{\sqrt{\mu_r \cdot \varepsilon_r}} = c_0 \cdot \frac{1}{\sqrt{\mu_r \cdot 1}}$$

The size of the loop has to be compensated for the change in speed of the radiation. The loop looks bigger.

$$\Phi = B \cdot e \cdot b = \mu \cdot H \cdot e \cdot b = \mu_0 \mu_r \cdot H \cdot e \cdot b = \mu_0 \cdot H \cdot (e\sqrt{\mu_r}) \cdot (b\sqrt{\mu_r})$$

Dielectric in an inductor?

If we insert a dielectric medium in an inductor the speed of the radiation becomes slower. This should result in increased energy in the inductor, and larger inductance. But the ratio between E and H is changed due to the dielectric. E will decrease resulting in lower power density for the same current I in the inductor. The decrease in speed and the decrease in power density gives as a result that the stored energy is unchanged.

$$W = E \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = Z \cdot H \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = \sqrt{\frac{\mu}{\varepsilon}} \cdot H \cdot H \cdot abe \cdot \sqrt{\mu \cdot \varepsilon} = \mu H \cdot H \cdot abe = B \cdot H \cdot abe$$

But the dielectric will affect the inductor. There will be larger ”stairs” in the charging curve. But the stored energy as a function of the current I in the inductor is unchanged. And concequently the inductance is unchanged.

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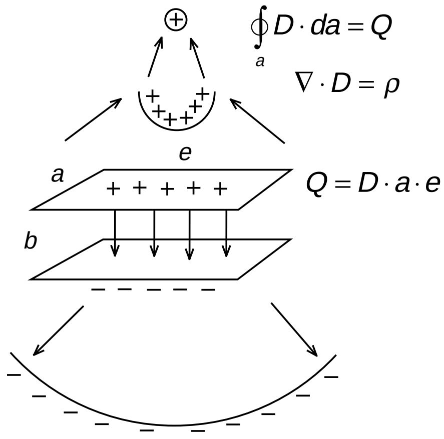
7. Fields from Radiation: The electron

7.1 A charged particle

A positiv charge

It is very simple. Start with a capacitor and diminish the capacitor plate with a positive charge into a point. At the same time, let the negative capacitor plate expand into infinity. Now we have a point charge, according to Gauss' law.

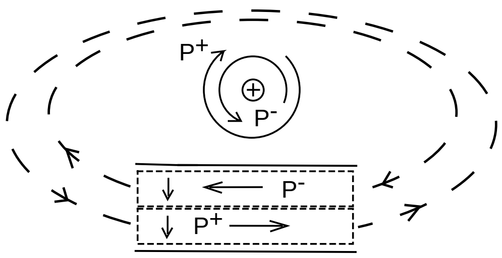


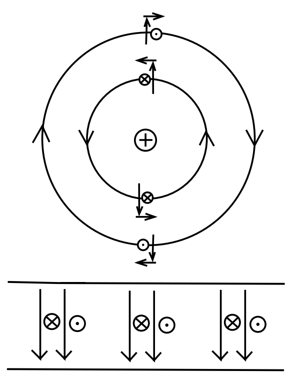
Forward and reflected radiation

Can we use forward and reflected radiation from the capacitor? Yes, we can. In the capacitor we have radiation that is reflected at the ends. Here, when the plates reach infinity the forward radiation will see its own tail and connect. The same happens with the reflected radiation.

Now we have two radiations encircling the point charge. The electric fields are pointing outward and add.

The magnetic fields are in concentric layers around the point charge and cancel in most areas, but not everywhere. This gives the spinn properties of the electron.

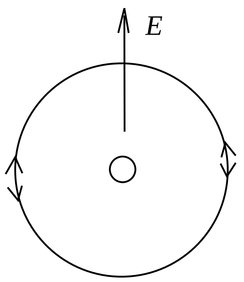


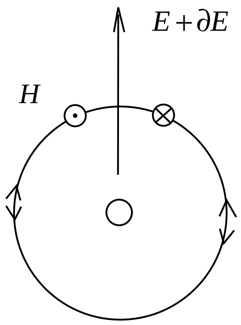


Start with a positive charge

The picture shows a positive charge, radiations encircling the point in opposite directions.

Look at an electric field *E* directed outwards from the ”point”.

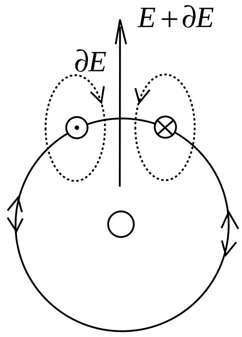




$$\nabla \times H = \varepsilon \cdot \frac{\partial E}{\partial t}$$

Suppose the electric field would like to change in amplitude

If the electric field will change in amplitude then there will be a magnetic field *H* induced, encircling the electric field according to Ampère’s law.



$$\nabla \times E = -\mu \cdot \frac{\partial H}{\partial t}$$

This will create amplitude changing magnetic fields

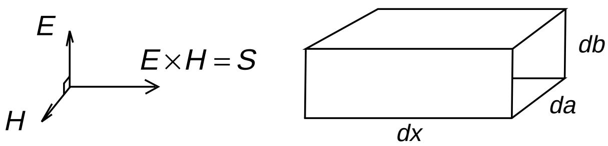
These new magnetic fields will be encircled by electric fields according to Faraday´s law, fields which will counteract the original change in electric field strange.

The point charge is a stable construction

A particle consisting of encircled radiations is a stable construction. As soon as it will change amplitudes or its chape, counteracting fields will be induced and prevent any change.

7.2 Energy in the radiation encircling the electron

Let us calculate the energy dW in the radiations in a small volume dV, using field strengths and the traditional speed of light:



$$\frac{E}{H} = Z_0 = \sqrt{\frac{\mu}{\varepsilon}} \quad \Rightarrow \quad H = \sqrt{\frac{\varepsilon}{\mu}} \cdot E$$

$$dW = n \cdot S_{part} \cdot dA \cdot dt = n\left(\frac{E}{n} \times \frac{H}{n}\right) \cdot da \cdot db \cdot \frac{dx}{c} = n \cdot \frac{E}{n} \cdot \left(\sqrt{\frac{\varepsilon}{\mu}} \cdot \frac{E}{n}\right) \cdot dV \cdot \sqrt{\mu \cdot \varepsilon} = \varepsilon \frac{E^2}{n} \cdot dV$$

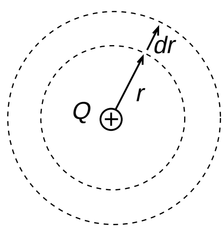
The energy is proportional to the square of the total electric field strength, but inversely proportional to the number *n* of radiations, and proportional to the volume of dV.

Look at a charged particle in the traditional way and calculate the total electric field strength from the charge Q of the particle.

$$E(r) = \frac{Q}{4\pi\varepsilon r^2}$$

Use this field strength for the calculation of energy in a shell volume element encircling the charge:

$$dW = \varepsilon \frac{E^2}{n} \cdot dV = \frac{\varepsilon}{n} \cdot \left(\frac{Q}{4\pi\varepsilon r^2}\right)^2 \cdot 4\pi r^2 \cdot dr = \frac{Q^2}{4\pi\varepsilon r^2 \cdot n} \cdot dr$$



Integrate from the surface of the electron to infinity, to calculate the total amount of energy that is encircling the electron:

$$W = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \int_{\Delta r}^{\infty} r^{-2} dr = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \left[-\frac{1}{r} \right]_{\Delta r}^{\infty} = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \frac{1}{\Delta r}$$

Now add some numerical data. We know the charge of the electron and the permittivity. But what is the radious of an electron? I use what is known as the classical radious of the electron:

$$\begin{cases} Q = 1,602 \cdot 10^{-19} \\ \varepsilon_0 = 8,85 \cdot 10^{-12} \\ \Delta r = 2,82 \cdot 10^{-15} \end{cases}$$

Total amount of energy encircling the electron:

$$W = \frac{Q^2}{4\pi\varepsilon_0 \cdot n} \cdot \frac{1}{\Delta r} = \frac{1}{n} \cdot \frac{\left(1,602 \cdot 10^{-19}\right)^2}{4\pi \cdot 8,85 \cdot 10^{-12} \cdot 2,82 \cdot 10^{-15}} = \frac{1}{n} \cdot 0,8183 \cdot 10^{-13}$$

Compare this with the energy which is ”contained” in the mass of the electron:

$$W = m \cdot c^2$$

$$\begin{cases} m = 9,11 \cdot 10^{-31} \\ c_0 = 2,998 \cdot 10^{8} \end{cases}$$

$$W = m \cdot c_0^2 = 9,11 \cdot 10^{-31} \cdot \left(2,998 \cdot 10^{8}\right)^2 = 0,8188 \cdot 10^{-13}$$

The energy encircling the electron as an electric field is equivalent to the mass of the electron, if the electric field is from only one radiation, $n = 1$. I suppose this is how the classical electron radious was calculated.

If n increases

Suppose we start with radiation encircling a sphere, only one radiation. This radiation is equivalent to all energy ”contained” in the electron, the ”mass” of the electron.

With n = 1 the radiation has to fill the space from infinity to the classic electron radious.

$$W_1(\infty, \Delta r) = \frac{Q^2}{4\pi\varepsilon \cdot 1} \cdot \int_{\Delta r}^{\infty} r^{-2} dr = \frac{Q^2}{4\pi\varepsilon \cdot 1} \cdot \left[-\frac{1}{r} \right]_{\Delta r}^{\infty} = \frac{Q^2}{4\pi\varepsilon} \cdot \frac{1}{\Delta r}$$

Use n = 2

Let n = 2. The electric field is created by two radiations in different directions (on the shells around the sphere), but the total field strength is unaltered.

$$W_2(\infty, \Delta r) = \frac{Q^2}{4\pi\varepsilon \cdot 2} \cdot \int_{\Delta r}^{\infty} r^{-2} dr = \frac{Q^2}{4\pi\varepsilon \cdot 2} \cdot \left[-\frac{1}{r} \right]_{\Delta r}^{\infty} = \frac{1}{2} \cdot \frac{Q^2}{4\pi\varepsilon} \cdot \frac{1}{\Delta r}$$

This time the energy from infinity to the classic electron radious only contains half the amount of energy.

Where is the missing energy?

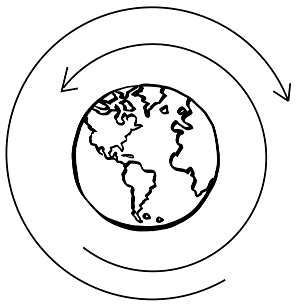
Calculate the energy from the classic electron radious to half of the classic electron radious:

$$W_2(\Delta r, \frac{\Delta r}{2}) = \frac{Q^2}{4\pi\varepsilon \cdot 2} \cdot \int_{\frac{\Delta r}{2}}^{\Delta r} r^{-2} dr = \frac{Q^2}{4\pi\varepsilon \cdot 2} \cdot \left[-\frac{1}{r} \right]_{\frac{\Delta r}{2}}^{\Delta r} = \frac{Q^2}{4\pi\varepsilon \cdot 2} \cdot \left(-\frac{1}{\Delta r} + \frac{2}{\Delta r} \right) = \frac{1}{2} \cdot \frac{Q^2}{4\pi\varepsilon} \cdot \frac{1}{\Delta r}$$

There is the missing energy.

What is an electron?

Suppose the creation of an electron started with one radiation encircling a sphere. Gradually the radiation was split into multipple radiations which did not alter the electric field strength, but forced the energy closer to the centre. If this goes on, the energy density close to the centre will be enormusly high, but there will still be an empty sphere in the middle, perhaps a tiny ”black hole”.

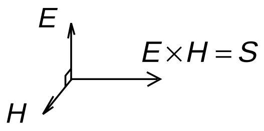


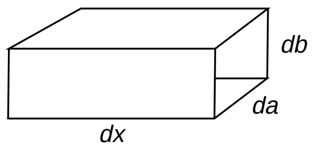
7.3 Thunderstorms, the creation of new electrons?

Radiation in the sky

Is the earth neutral or is it charged?

Measurements have shown that there is a field strength of 100 V/m in the direction towards the earth. The earth is negatively charged, or if we talk the language of radiation, the earth is encircled by radiations giving a field strength of 100 V/m. From the calculations of energy encircling the ”electron” we have that the total energy in a small volume element is proportional to ε_r .





$$\frac{E}{H} = Z_0 = \sqrt{\frac{\mu}{\varepsilon}} \Rightarrow H = \sqrt{\frac{\varepsilon}{\mu}} \cdot E$$

$$dW = \varepsilon \frac{E^2}{n} \cdot dV = \varepsilon_0 \cdot \varepsilon_r \frac{E^2}{2} \cdot dV = \left[\varepsilon_0 \frac{E^2}{2} \cdot dV \right] \cdot \varepsilon_r$$

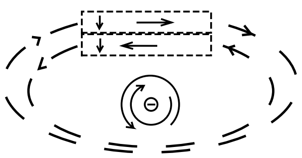
On a sunny day the atmosphere has $\varepsilon_r \approx 1$, giving a certain amount of energy inside a volume.

When it is raining, the cloud is a mixture of atmosphere and water (water has $\varepsilon_r \approx 80$). Boundary conditions are that the electric field must be the same both inside and outside the cloud.

When it starts to rain there will be multiple reflections at the borders of the cloud, The total amount of energy inside that volume will grow until the electric field is the same as outside the cloud.

When it stopps raining, the boundary conditions are not fulfilled. With $\varepsilon_r \approx 1$ the electric field is too large with that amount of energy inside the volume.

This extra energy which was part of radiations encircling the earth when it was raining, is released. The ends of the radiations have nowhere to go, but to connect to each other. Suddenly we have radiations going in a circle.



Dielectric in the sky

The rest is handled by Faraday´s and Ampère´s laws. The radiations are compressed into a ”particle”, and nature has created a new electron or positron.

7.4 The double slit experiment

The double slit experiment is famous in showing the dual nature of the electron. Is the electron a particle? or is it a wave function?

1. When electrons are shot against a screen with one slot, the detector screen will show a standard propability distribytion.

2. If there are two slots in the screen the detector screen will show an interference distribution, as in experiments with light.

3. If we put detectors at the slots and measure the number of electrons passing through each slot, then the detector screen will show two standard propability distributions, not an interference distribution...

4... but if we switch off the detectors at the slots, they are still there, then the detector screen shows an interference distribution.

If the electron is an empty space surrounded by radiations extended to infinity

Suppose the electron really is the radiations encircling it, not a particle in the centre

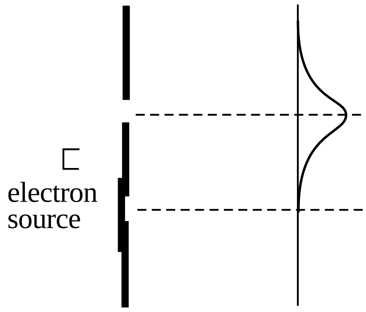
1. The radiations will squeeze through the slot and combine into an electron.

2. With two slots some part of the radiations will squeeze through one slot, and the remaining radiations will squeeze through the other slot. At the back of the screen this is an electron with its radiations distorted in such a way that it can only exist in certain directions, as indicated by the interference distribution.

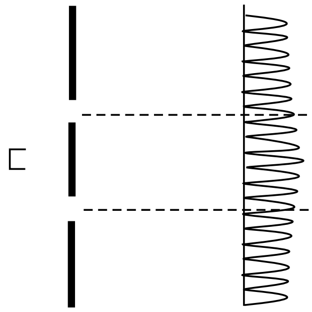
3. When such a distorted electron is ”detected” we reorganise the radiations to form an undistorted standard electron. With two detectors, one at each slot, the result is as if the electrons where emitted from the detectors at the slots, not going through the slots. On the detector screen we see two standard propability distributions, no trace of interference.

4. When the detectors are switched off the detectors will no longer reorganise the radiations to form undistorted electrons, and on the detector screen we have the interference distribution.

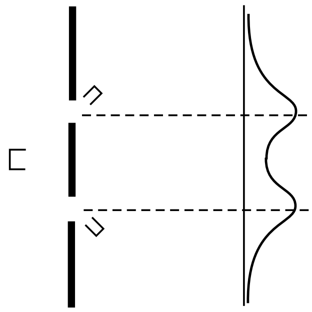
The electrons can recognise if the detectors are ”detecting” or not!



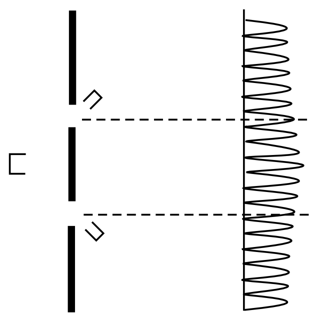
1. One slot



2. Two slots



3. Two slots with detectors



4. Two slots but detectors are shut off

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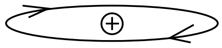
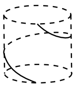
8. Energy of movement, kinetic energy

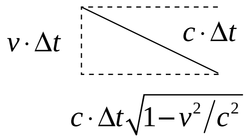
8.1 Electron in motion

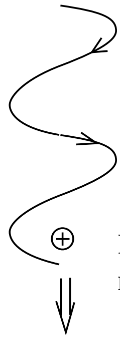
The radiations encircling a resting electron are running with the speed of light. If the electron starts moving the radiations will run in an orbit formed like a helix. To still complete a full turn with the same speed, the radious must decrese.



Resting particle







Particle in motion

$$\begin{cases} 2\pi r_0 = c \cdot \Delta t \\ 2\pi r_v = c \cdot \Delta t\sqrt{1-v^2/c^2} = 2\pi r_0\sqrt{1-v^2/c^2} \end{cases}$$

$$r_v = r_0\sqrt{1-v^2/c^2}$$

Increase in energy

If the inner radious in the radiations encircling the centre is decreasing without dividing the radiations into more radiations, the total energy associated with the particle will increase:

$$W(v) = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \int_{\Delta r\sqrt{1-v^2/c^2}}^{\infty} r^{-2}\,dr = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \left[-\frac{1}{r}\right]_{\Delta r\sqrt{1-v^2/c^2}}^{\infty} = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \frac{1}{\Delta r\sqrt{1-v^2/c^2}} = \frac{W}{\sqrt{1-v^2/c^2}}$$

Compare the energi in a resting electron with an electron in motion. The difference is the relativistic energy of movement.

$$\begin{cases} W = \dfrac{Q^2}{4\pi\varepsilon \cdot n} \cdot \dfrac{1}{\Delta r} = m_0 \cdot c^2 \\ W(v) = \dfrac{Q^2}{4\pi\varepsilon \cdot n} \cdot \dfrac{1}{\Delta r\sqrt{1-v^2/c^2}} = \dfrac{m_0}{\sqrt{1-v^2/c^2}} \cdot c^2 \end{cases}$$

$$W(v) = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \frac{1}{\Delta r\sqrt{1-v^2/c^2}} = \frac{m_0}{\sqrt{1-v^2/c^2}} \cdot c^2 \approx m_0 \cdot c^2\left(1+\frac{1}{2}v^2/c^2\right) = m_0 \cdot c^2 + \frac{1}{2}m_0 \cdot v^2$$

If the particle is moving at low speed, then we can simplify:

$$W(v) = \frac{Q^2}{4\pi\varepsilon \cdot n} \cdot \frac{1}{\Delta r\sqrt{1-v^2/c^2}} = \frac{m_0}{\sqrt{1-v^2/c^2}} \cdot c^2 \approx m_0 \cdot c^2 \left(1+\frac{1}{2}v^2/c^2\right) = m_0 \cdot c^2 + \frac{1}{2}m_0 \cdot v^2$$

What we see is the energy associated with the particle at rest:

$$m_0 \cdot c^2$$

and the energy of movement:

$$\frac{1}{2}m_0 \cdot v^2$$

Energy of movement

If we accept that the particle consists of radiations encircling an empty hole in the middle, then the energy of movement is ”stored” closest to the hole. For a particle in motion the hole is smaller, and it is in this space that we have the energy associated with the motion of the particle.

8.2 Conservation of energy

Collision of two particles with masses m_1 and m_2 and velocities v_1 and v_2. The total energy shall be the same before and after the collision.

$$\frac{m_1}{\sqrt{1-v_1^2/c^2}}\cdot c^2+\frac{m_2}{\sqrt{1-v_2^2/c^2}}\cdot c^2=\frac{m_1}{\sqrt{1-v_3^2/c^2}}\cdot c^2+\frac{m_2}{\sqrt{1-v_4^2/c^2}}\cdot c^2$$

If the speeds are low compared to the speed of light, this can be simplified using:

$$\frac{m_0}{\sqrt{1-v^2/c^2}}\cdot c^2\approx m_0\cdot c^2\left(1+\frac{1}{2}v^2/c^2\right)=m_0\cdot c^2+\frac{1}{2}m_0\cdot v^2$$

and we get:

$$m_1c^2+\frac{1}{2}m_1v_1^2+m_2c^2+\frac{1}{2}m_2v_2^2=m_1c^2+\frac{1}{2}m_1v_3^2+m_2c^2+\frac{1}{2}m_2v_4^2$$

or the well known formula for conservation of energy of movement, which is only valid at low speeds:

$$\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2=\frac{1}{2}m_1v_3^2+\frac{1}{2}m_2v_4^2$$

Conservation of momentum

Not only shall the total energy be unaltered, the total energy transported in different directions shall be unaltered.

Energy transport in one direction is energy times speed, where speed is a vector.

$$\frac{m_1}{\sqrt{1-v_1^2/c^2}}\cdot c^2\cdot\boldsymbol{v}_1$$

This gives the following:

$$\frac{m_1}{\sqrt{1-v_1^2/c^2}}\cdot c^2\cdot\boldsymbol{v}_1+\frac{m_2}{\sqrt{1-v_2^2/c^2}}\cdot c^2\cdot\boldsymbol{v}_2=\frac{m_1}{\sqrt{1-v_3^2/c^2}}\cdot c^2\cdot\boldsymbol{v}_3+\frac{m_2}{\sqrt{1-v_4^2/c^2}}\cdot c^2\cdot\boldsymbol{v}_4$$

At low speeds this gives:

$$\left(m_1\cdot c^2\cdot\boldsymbol{v}_1+\frac{1}{2}m_1v_1^2\cdot\boldsymbol{v}_1\right)+\left(m_2\cdot c^2\cdot\boldsymbol{v}_2+\frac{1}{2}m_2v_2^2\cdot\boldsymbol{v}_2\right)=\left(m_1\cdot c^2\cdot\boldsymbol{v}_3+\frac{1}{2}m_1v_3^2\cdot\boldsymbol{v}_3\right)+\left(m_2\cdot c^2\cdot\boldsymbol{v}_4+\frac{1}{2}m_2v_4^2\cdot\boldsymbol{v}_4\right)$$

At low speeds the first part of every term is dominating and we get the well known relation for conservation of momentum:

$$m_1\boldsymbol{v}_1+m_2\boldsymbol{v}_2=m_1\boldsymbol{v}_3+m_2\boldsymbol{v}_4$$

Two formulas, with approximations:

$$\begin{cases}\frac{1}{2}m_1v_1^2+\frac{1}{2}m_2v_2^2=\frac{1}{2}m_1v_3^2+\frac{1}{2}m_2v_4^2\\ m_1\boldsymbol{v}_1+m_2\boldsymbol{v}_2=m_1\boldsymbol{v}_3+m_2\boldsymbol{v}_4\end{cases}$$

but we only need one formula:

If we use the original /relativistic) formula for conservation of momentum of the energies, we only need one formula:

$$\frac{m_1}{\sqrt{1-v_1^2/c^2}}\cdot\boldsymbol{v}_1+\frac{m_2}{\sqrt{1-v_2^2/c^2}}\cdot\boldsymbol{v}_2=\frac{m_1}{\sqrt{1-v_3^2/c^2}}\cdot\boldsymbol{v}_3+\frac{m_2}{\sqrt{1-v_4^2/c^2}}\cdot\boldsymbol{v}_4$$

Another way is to use the energies:

$$\frac{W_1(v)}{c^2}\cdot\boldsymbol{v}_1+\frac{W_2(v)}{c^2}\cdot\boldsymbol{v}_2=\frac{W_3(v)}{c^2}\cdot\boldsymbol{v}_3+\frac{W_4(v)}{c^2}\cdot\boldsymbol{v}_4$$

$$\boldsymbol{p}_1+\boldsymbol{p}_2=\boldsymbol{p}_3+\boldsymbol{p}_4$$

By using energies instead of masses, it is much easier to understand what is happening when energy (radiation) is released at the collision. This radiation can be transformed into new particles or radiate as electromagnetic waves, photons.

Momentum of a photon:

$$\boldsymbol{p}=\frac{W}{c^2}\cdot\boldsymbol{c}$$

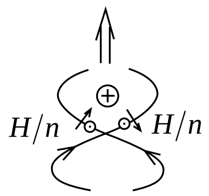
9. Ampère’s law

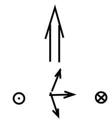
9.1 Magnetic fields from electrons in motion

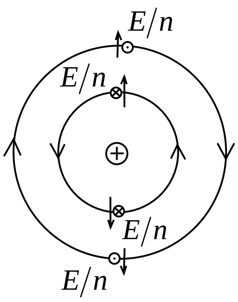
When the electron is moving the radiations will rotate in a helix formed way and the magnetic fields will no longer cancel. There will be a magnetic component encircling the electron trajectory.

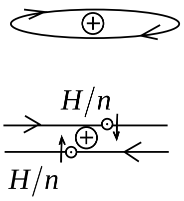
Electrons in motion is current. This magnetic field is described by Ampère's law.

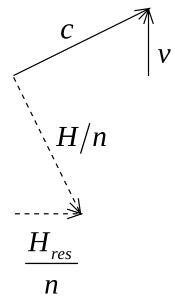
To keep it simple, use a positive sharge instead of an electron.





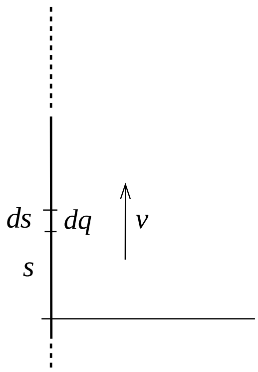






$$\frac{H_{res}}{n} = \frac{H}{n} \cdot \frac{v}{c}$$

When the positive charge is moving with the speed and direction of v, there will be a magnetic field component H_{res}/n from each of the magnetic fields encircling the direction of motion.

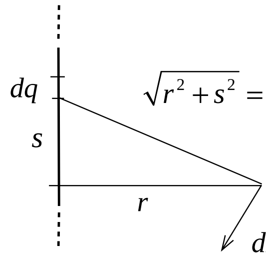


$$dq = Q_m \cdot ds$$

$$I = Q_m \cdot v$$

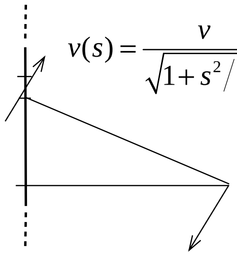
Study a small piece of a conductor *ds* carrying current. The total charge in ds is *dq*, calculated from total charge per meter Q_m. The current is calculated when we know the speed *v* of the charges.

From the total electric field produced by dq, use the ratio between E and H, the characteristic impedance, to calculate the total magnetic field. We have no use for the individual magnetic fields because we do not calculate power density.



$$\sqrt{r^2+s^2}=r\sqrt{1+s^2/r^2}$$

$$dH=\frac{1}{Z_0}\cdot\frac{dq}{4\pi\varepsilon r^2(1+s^2/r^2)}$$



$$v(s)=\frac{v}{\sqrt{1+s^2/r^2}}$$

Now calculate the small encircling magnetic field as a function of distance from *ds*.

$$dH_{res}=\frac{1}{Z_0}\cdot\frac{dq}{4\pi\varepsilon r^2(1+s^2/r^2)}\cdot\frac{v(s)}{c}=\frac{1}{Z_0}\cdot\frac{dq}{4\pi\varepsilon r^2(1+s^2/r^2)}\cdot\frac{v}{\sqrt{1+s^2/r^2}}\cdot\frac{1}{c}$$

Use earlier definitions:

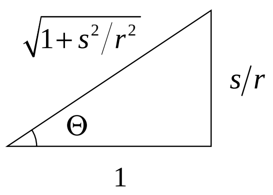
$$dH_{res}=\sqrt{\frac{\varepsilon}{\mu}}\cdot\frac{dq\cdot v}{4\pi\varepsilon r^2(1+s^2/r^2)^{\frac{3}{2}}}\cdot\sqrt{\mu\varepsilon}=\frac{Q_m\cdot ds\cdot v}{4\pi r^2(1+s^2/r^2)^{\frac{3}{2}}}=\frac{I}{4\pi r^2}\cdot\frac{ds}{(1+s^2/r^2)^{\frac{3}{2}}}$$

Integrate along the line from $-\infty$ to $+\infty$:

$$H_{res}=2\cdot\frac{I}{4\pi r^2}\int_0^{\infty}\frac{ds}{(1+s^2/r^2)^{\frac{3}{2}}}=\frac{I}{2\pi r}\int_0^{\infty}\frac{1}{r}\cdot\frac{ds}{(1+s^2/r^2)^{\frac{3}{2}}}$$

To solve do the following substitutions:

$$\int_0^\infty \frac{1}{r}\cdot\frac{ds}{(1+s^2/r^2)^{\frac{3}{2}}} = \int_0^\infty \frac{1}{\sqrt{1+s^2/r^2}}\cdot\frac{1}{(1+s^2/r^2)}\cdot\frac{1}{r}\cdot ds$$



$$\begin{cases} \tan\Theta = s/r \\ \Theta = \arctan s/r \\ d\Theta = \dfrac{1}{\left(1+s^2/r^2\right)}\cdot\dfrac{1}{r}\cdot ds \\ \dfrac{1}{\sqrt{1+s^2/r^2}} = \cos\Theta \end{cases}$$

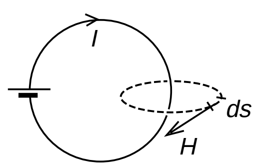
which makes it easier:

$$\int_0^\infty \frac{1}{\sqrt{1+s^2/r^2}}\cdot\frac{1}{(1+s^2/r^2)}\cdot\frac{1}{r}\cdot ds = \int_0^{\pi/2} \cos\Theta\cdot d\Theta = \left[\sin\Theta\right]_0^{\pi/2} = 1-0 = 1$$

9.2 Ampère’s law

Now it is easy to calculate the total magnetic field encircling the current in a conductor:

$$H_{res} = \frac{I}{2\pi r}\int_0^\infty \frac{1}{r}\cdot\frac{ds}{(1+s^2/r^2)^{\frac{3}{2}}} = \frac{I}{2\pi r}$$



$$\oint H\cdot ds = H\cdot 2\pi r = I$$

I started with the assumption that a charged particle consists of electromagnetic radiation, and from that and some trigonometric calculations I ended up with Ampère’s law.

10. Potential energy

10.1 A force between charges

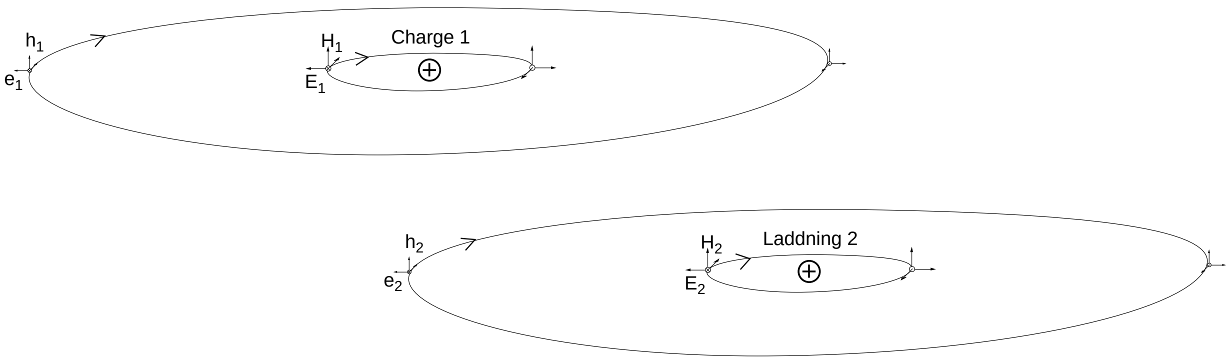
A force can do work

Two positive ”particles” are repelling. There is a force between them. To bring the ”particles” closer together means a work must be done. Work is energy. When we have brought the ”particles” closer they have potential energy. Where is this energy stored?

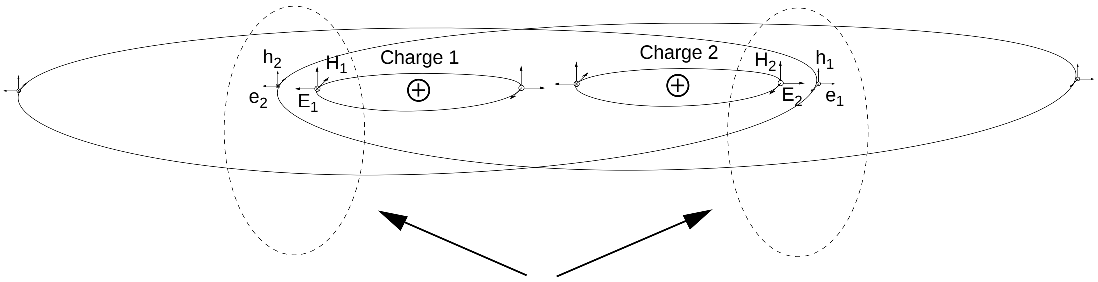
The kinetic energy in a moving ”particle” is stored close to the centre in the radiations encircling the ”particle” (or hole). Where is the potential energy stored?

10.2 Energy is stored ...

Around every ”particle” we have the encircling radiations. When two ”particles” are together their radiations occupy the same space. Start with the radiations rotating clockwise.



If radiations go in the same direction, we have to add their fields, which results in much higher energy density if the fields add, or substantially lower energy density if the fields subtract.



In these areas energy is stored

$$S_1 \sim E_1^2$$
$$S_2 \sim e_2^2$$
$$S_{tot} \sim (E_1 + e_2)^2 = E_1^2 + e_2^2 + 2 \cdot E_1 e_2$$

$$S_1 \sim e_1^2$$
$$S_2 \sim E_2^2$$
$$S_{tot} \sim (e_1 + E_2)^2 = e_1^2 + E_2^2 + 2 \cdot e_1 E_2$$

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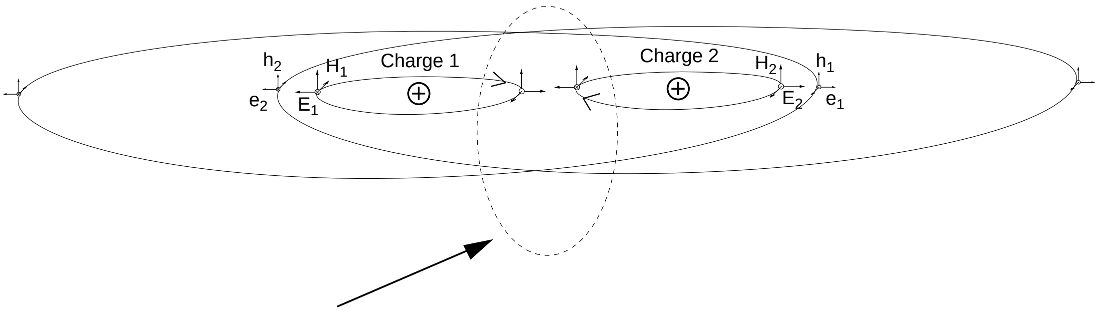
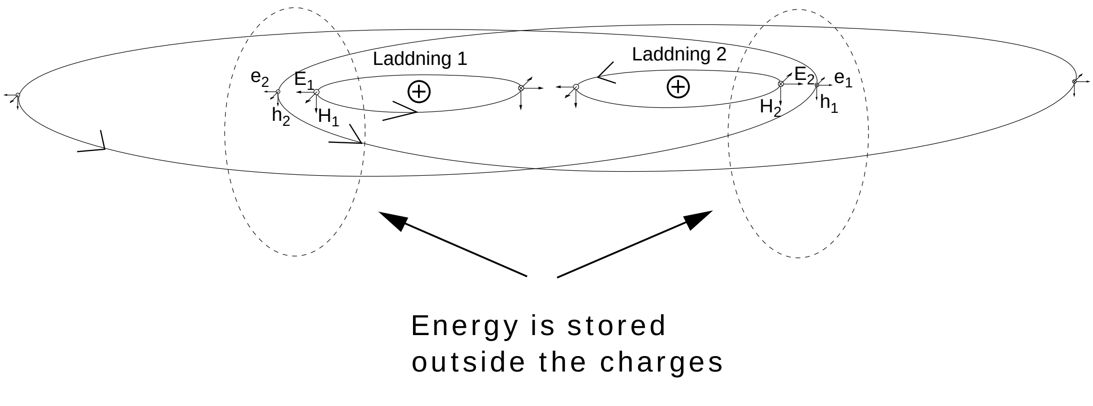
In the area outside the charges these clockwise radiations travel in the same direction. Then we have to add the fields and in this case the sum will be larger, which means that the radiation density is larger than the sum of the two radiation densities. In this area potential energy is stored.



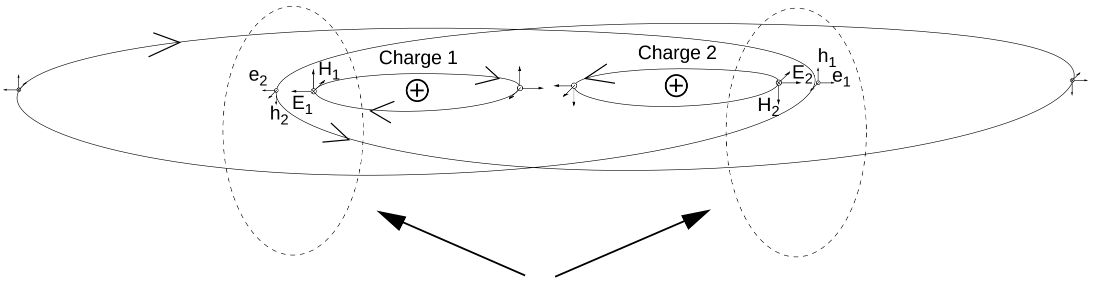
In the area between the charges the clockwise radiations go in opposite directions and do not interfer. Nothing happens here from these radiations

But there are also radiations going in anticlockwise direction.

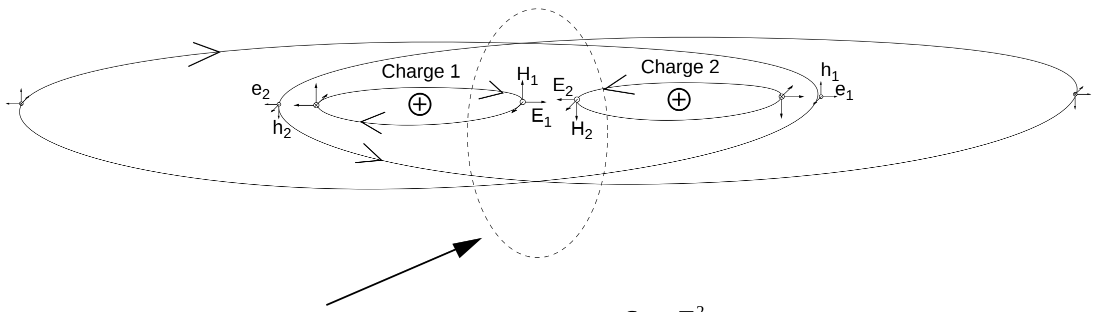


Radiations encircling anticlockwise will store energy in the area outside of the ”particles”, and between the ”particles” the radiations go in opposite directions and nothing happens there.

10.3 ... and energy is released



If we study clockwise radiation from ”particle 1”, and anticlockwise radiation from ”particle 2”, nothing happens in the area outside the ”particles”.



In this area energy is released

$$S_1 \sim E_1^2$$
$$S_2 \sim E_2^2$$
$$S_{tot} \sim (E_1 - E_2)^2 = E_1^2 + E_2^2 - 2 \cdot E_1 E_2$$

This time, in the area between the ”particles”, we have radiations travelling in the same direction, with field strengths in opposite directions. The total energy density in this area will be less than the energy from each ”particle”. Energy is released.

How much energy is stored? How much is released?

I have not been able to calculate the energies, but simple calculations in a solid angle in the directions going through the two ”particles” indicate, that somewhat more energy is stored in the outside regions than is released between the ”particles” when the particles are far apart.

If this is the case you must add energy to move the ”particles” closer.

One single charged ”particle”

One single ”particle” consists of radiations encircling an empty space, a hole. The total energy of the ”particle”, both its mass and kinetic energy, is stored in the encircling radiations.

Two positive or negative charged ”particles”

In the radiations encircling two ”particles” of the same polarity, energy is moved from the area between the ”particles” to the space outside the ”particles”.

But this is not enough. Further energy must be added when we push the ”particles” closer. This extra energy being added is the potential energy, which is released when the ”particles” are allowed to separate.

One positive and one negative ”particle”

With two ”particles” of the same polarity we concluded that energy is stored outside the ”particles”, and energy is released between the ”particles”. More energy is stored than released. The ”particles” repel each other.

With ”particles” of opposite polarity, everything is reversed. Energy is released in the area outside the ”particles”, but stored between the particles. More energy is released than stored. Nature strive to reach the state of least total energy. The ”particles” attract.

A neutral ”particle”

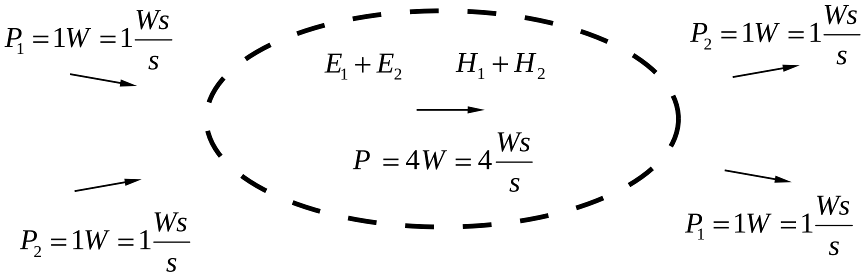
Can the ”particles” merge into each other? No, the closer they get, the more energy is stored in the space between the ”particles” and the less energy is left for the outside world. Finaly they become a ”neutral particle”, with mass symbolized by the energy stored in the space between the ”particles”. But it is still two ”particles” and will always be.

Remember that we always have radiations encircling each ”particle”. What happens is that the fields from these radiations are in opposite phase, meaning that the sum of the radiations can not contain energy. But there are still a lot of radiations!

10.4 What if we study the radiations?

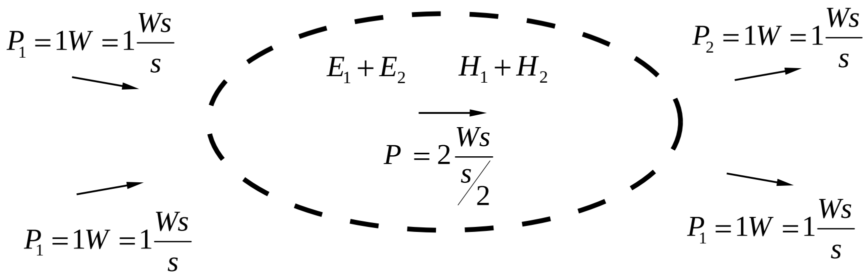
Two radiations entering a common space

Suppose we have two radiations of equal strength entering a common volume. Inside the volume we can not add the radiations but have to add the fields.



A total power of 2 W is entering the volume every second, and the same power is leaving the volume every second. But the total energy inside the volume is as if 4 Ws is moving with the speed of light.

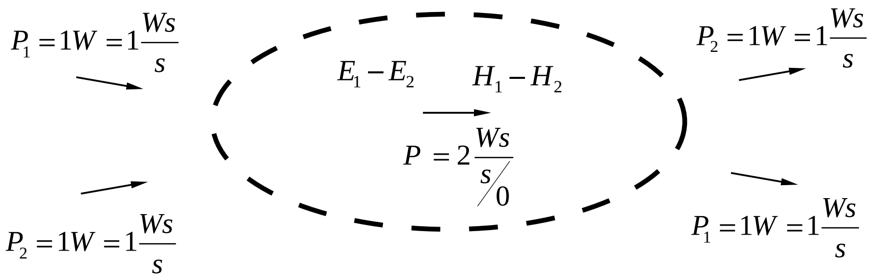
Suppose the radiations affect each other so that we still have 2 Ws moving, but moving with half the speed of light. Then the total energy inside the volume is as if 4 Ws is moving with the speed of light, but the two radiations are now travelling unaffected through the volume, only their speed is changed.



Suppose the radiations are in antiphase. Then there should be no energy at all inside the volume, but still 2 Ws per second is leaving the volume at the other end.

How can 2 Ws of energy move through the volume, but the total energy inside that volume be zero?

It can if the energy is moving very fast. Suppose the speed is infinity, then the energy is moving through the volume but the energy density inside the volume is zero.



10.5 Big Bang and the speed of expansion

At Big Bang an enormous amount of energy was produced which expanded (in all directions?).

- The amount of energy was so high that the energy density must have been unbelivable high.

- In the first moment the expansion reached so far that the energy must have travelled much faster than the speed of light.

Suppose this was independent radiations, in all different polarizations. Then there must have been radiations travelling in almost the same direction, with polarizations in antiphase.

If my assumption above is correct, these radiations in antiphase interact in such a way that the combined energy density is much smaller than the sum of energy densities from each individual radiation, and the reason for this is that these radiations in antiphase travel at a speed much faster than the traditional speed of light.

The result of assumptions based on the radiation model described in this paper is,

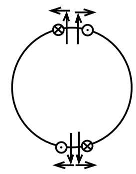
— that the expansion of energy after the Big Bang was faster than the traditional speed of light,

— and this higher speed of propagation gives that the energy density at the point of Big Bang was not infinitely high.

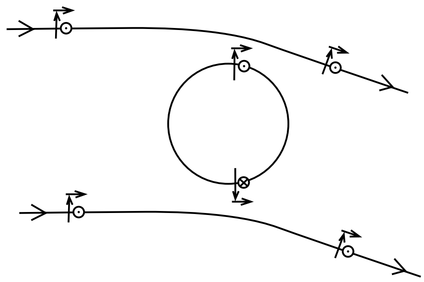
10.6 When radiation change direction

Radiation from a star meets other stars

When radiation, i.e. light from a distant star, is travelling in the neighbourhood of a planet or star surrounded by encircling radiations, we have radiations in the same direction in phase on one side and in antiphase on the other side of the star.

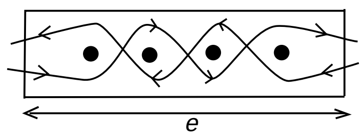


Suppose radiations in phase store more energy making the radiations go slower, and radiations in antiphase release energy making the radiations go faster. This will result in the lightwave bending downwards.



Is this what happens in a dielectric?

Could it be something like this that happens in a dielectric or magnetic medium? Is the radiation slalom-skiing around the molecules?



The distance is longerer and the speed itself is slower due to storing energy when bending around the molecules? Stored energy in the medium?

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11. Forces between particles, gravity

True definition of a force!

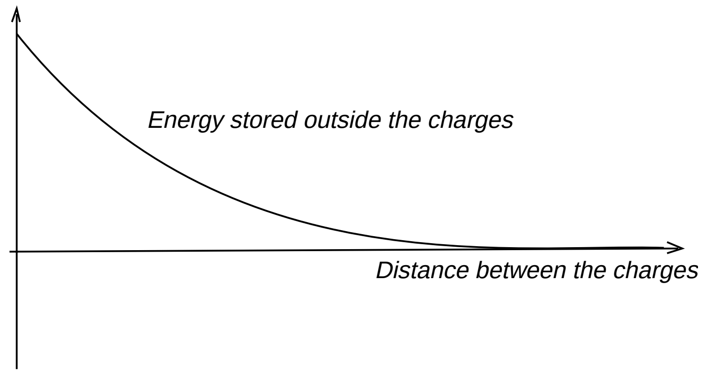
If energy is needed or energy is released when objects are moved in relation to each other, then we have a force.

Force equals the derivative of total energy to distance.

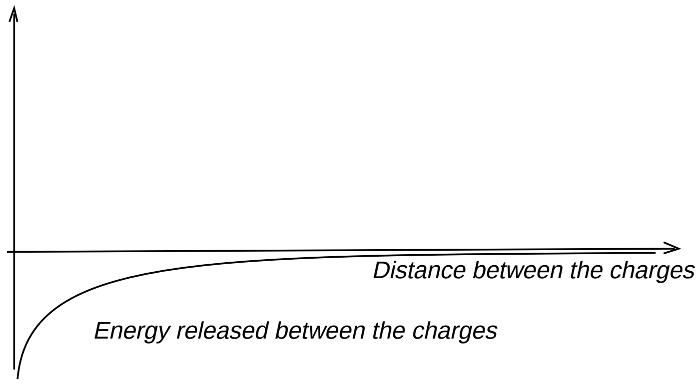
Total energy is energy associated with the masses plus total kinetic energy plus total potential energy in the objects and everything in the surroundings (including the whole universe).

11.1 Energy is stored — energy is released

We have two fenomenon in the area occupied by the two positive ”particles”, the two positive charges: Outside the charges energy is stored when we press the charges closer to each other.



At the same time energy is released from the area between the charges.



Imagine that the sum of stored energy and released energy have a maximum at some distance between the charges, a critical distance.

When the charges are further apart than the critical distance, energy must be added to bring the charges closer. But as soon as you reach the critical distance, more energy is released than stored. The charges no longer repel, but attract!

11.2 Two positive particles

Change the positive charge into a heavy positive particle, consisting of a combination of positive and negative charges but with an extra positive charge. Far away there is an electric field which comes from the extra positive charge. This field (radiation) represents only a fraction of the total mass of the particle.

The main part of the radiation, the radiation which is needed to represent the total mass of the particle, is concentrated between and in close vicinity to the negative and positive charges which looks as the neutral part of our particle.

Take two heavy positive particles like this:

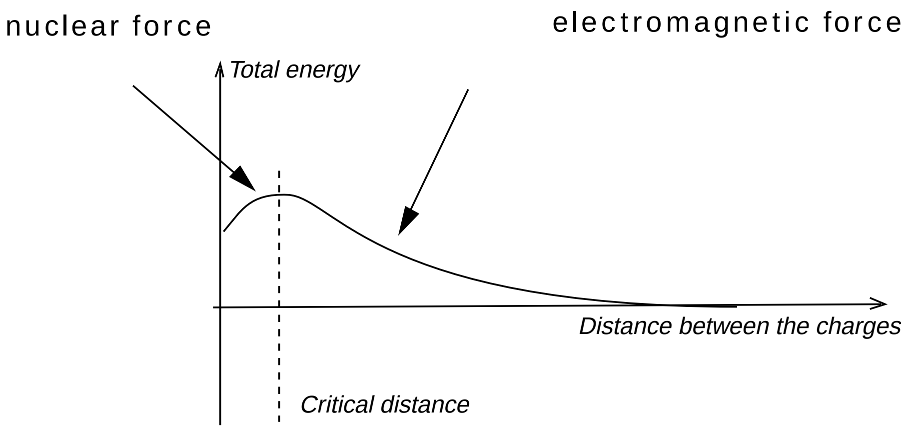
The electromagnetic force

When the particles are far apart, everything looks like the two positive charges which we already have studied. There is a force which repel the particles, an electromagnetic force. We must add energy to bring the particles together, because more energy is stored in the radiations encircling the two particles than is released in the area between the particles.

But suddenly, at some distance, more energy is released from the area between the particles than is stored outside the particles. We have reached a critical distance, at which the positive particles no longer repel, but attract each other.

Nuclear force (residual strong force)

This force, which make positive particles attract, is the force which make the protons in the nucleus keep together.

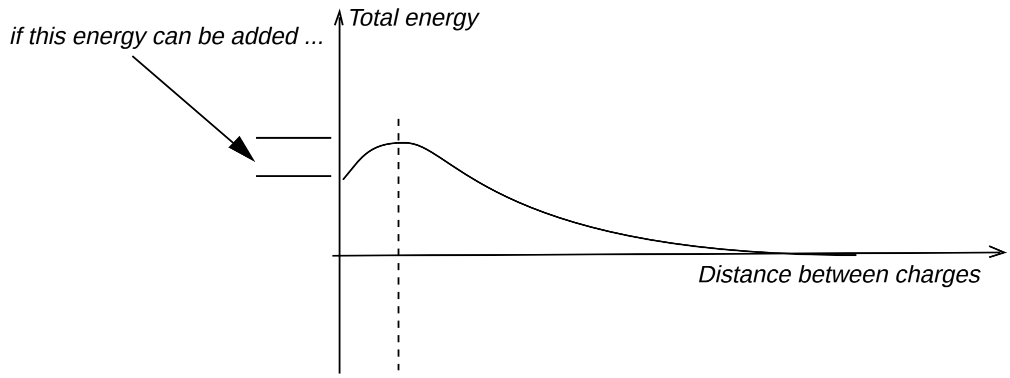


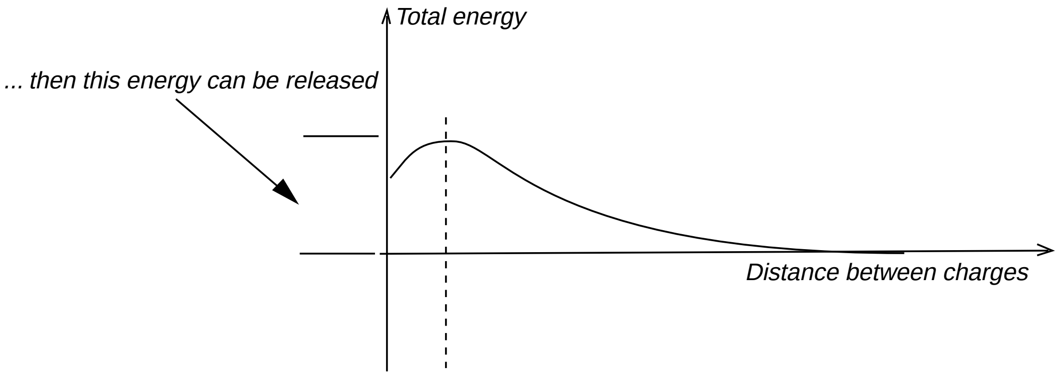
To split a nucleus

If we manage to add the energy nessesary to separate the two positive particles to reach the critical distance, then they will repel and energy is released.

If the released energy is enough to split another nucleus, then we have a slow radioactive disintegration.

If the released energy is enough to split two nuclei we have atomic power.





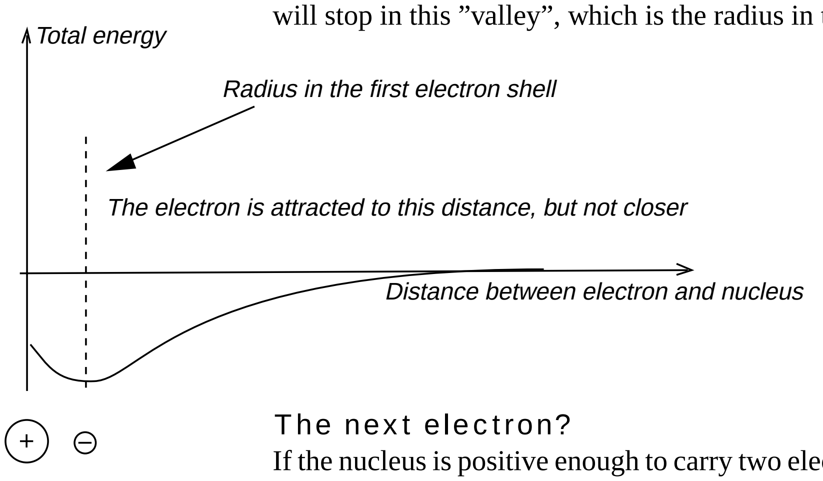
11.3 The atomic nucleus and the first electron

Start with a heavy positive particle, in this case the atomic nucleus, and add an electron which is negative. What happens when they come closer?

One particle is positive and the other is negative. In this case energy is released outside the particles, but stored between the particles.

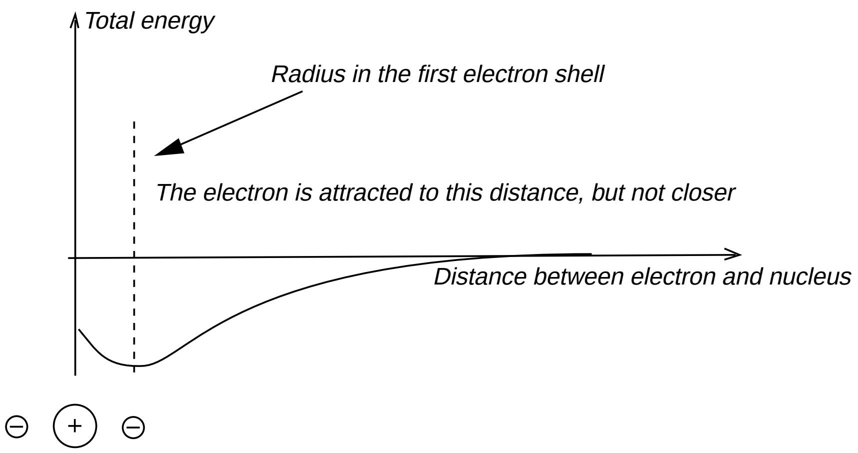
First, when they come closer, more energy is released outside the particles than stored between them. The electron is attracted by the atomic nucleus.

Suddenly the electron reaches a distance where more energy will be needed than is released to come closer to the nucleus. The electron will stop in this ”valley”, which is the radius in the first electron shell.



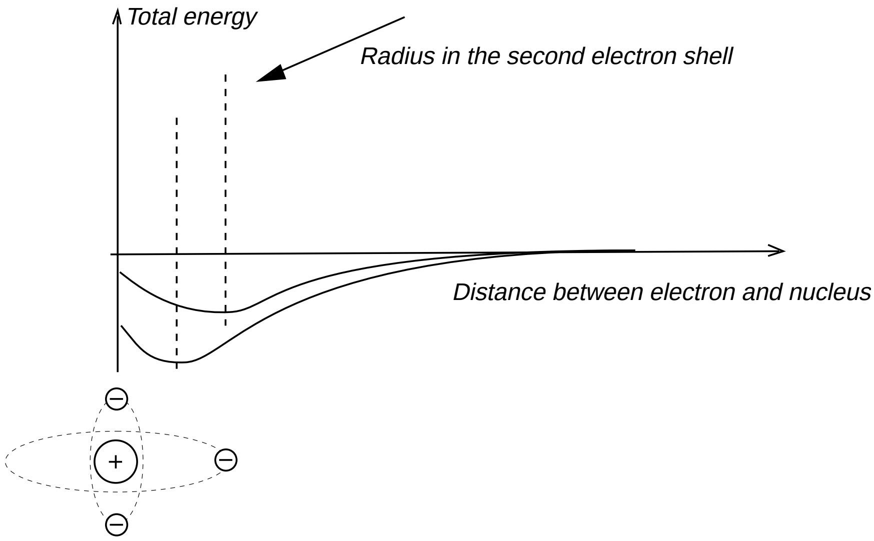
The next electron?

If the nucleus is positive enough to carry two electrons, the second electron will look for the ”energy valley” created by the nucleus and the first electron. The point with minimum energy, the point where most energy is released, is at the same distance but opposite to the first electron.



Still another electron

When there are two electrons close to the nucleus, the combined energy pattern is changed. The third electron will find an energy minimum in the plane of symmetri between the first two electrons. This energy minimum is at a larger distance from the nucleus, and is not that deep. This third electron is not tied that hard to the nucleus.



Atoms according to the radiation hypothesis

The electrons will place themselves in a ”valley” where the total energy is minimum. If the electron has energy of its own (kinetic energy, i.e. from heat), it does not stay in the bottom of the valley but moves up and down the valley slopes.

How many electrons can find a valley in shell number two? My gess is eight electrons. With eight electrons no more valleys are possible at this distance, and the next electron will find a valley at a larger distance, in shell number three.

Before shell number two is full with eight electrons there is an intermediate state. In directions where shell number two looks full there is a valley at shell number three, but in other directions where it is not full, the valley is at shell number two. An electron can choose between the two shells, shell number two or number three.

If the electron choose shell number three but later jumps to shell number two, energy is released, because that valley is deeper. This released energy is radiated.

The probability for electrons to ”jump” between shells is largest when the outermost shell is half full.

Solids and molecules

When atoms combine into solids, they search a minimum in total energy. The atoms together with their electrons position themselves in such a way that all individual radiations combine into minimum total energy.

Studying the energy gives answer to all questions about the structure of moleculs, and the forces that keep them together.

11.4 Particles and radiation

Energy is released when we split an atom nucleus. What happens with that energy?

It can radiate as electromagnetic radiation. But there are other possibilities.

A negative particle, i.e. an electron e, consists of electromagnetic radiation going in circles. But there are also antiparticles, identical to the electron, but positive, the positron $\overline{e}$, where the electromagnetic radiation is in antiphase.

What happens if we add two of these particles, if we combine them to overlap, so that all radiation going in circles cancel? Then the energy should take the form of radiation travelling not in circles but in straight lines. Energy in circles which we associate with mass has been converted into a "packet" of energy which could be a "photon", and this energy is travelling with the speed of light.

A neutral particle must consist of positive and negative particles with a tiny space between the particles. If there is no space, if the particles completely overlap, then there are no particles.

11.5 New particles

Now start with energy in the form of radiation travelling straight ahead. This energy can be converted into particles, but it must always be a pair, the particle and its antiparticle. One will be positive, the other negative. One will spin in one direction, the other will spin in the other direction.

If one proton is accelerated into another proton, then another proton can be created, but also an antiproton.

$$p + p \to p + p + p + \overline{p}$$

This should be written as

$$(p + energy\ of\ movement) - (p + energy\ of\ movement) \to p + p + p + \overline{p}$$

It is clear that energy of movement has been converted into mass, a new proton and an antiproton.

11.6 Gravity

It is possible that the kinetic energy is stored inside each charge, ”particle”, nearest to the centre of each ”particle”, and that the potential energy is in the interactions between the radiations surrounding individual particles, each group of particles, between objects, planets or stars.

When radiations mix the density of energy can be higher or lower than the sum of the radiations, as explained in chapter 10. If energy can be released, the bodies try to organize themselves to minimize the total energy.

A force is the derivative of total energy to distance. How much energy that can be released or is needed and how it change with distance, depends on the distance (geometry) between the particles or bodies. This have resulted in the definition of different forces, the nuclear force, the electromagnetic force and the gravity force.

They are all of the same origin, but

Because energy can be stored or released both outside the bodies, and released or stored between the bodies, the sum of these, outside and between, hehaves differently depending on the charge polarity and the distance between the bodies. Therefore experiments have resulted in different formulas, but they are all of the same origin.